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SCIENCE IN INDUSTRY

Policy for Progress

Oxford University Press, Amen House, London E.C.4
GLASGOW NEW YORK TORONTO MELBOURNE WELLINGTON
BOMBAY CALCUTTA MADRAS KARACHI KUALA LUMPUR
CAPE TOWN IBADAN NAIROBI ACCRA

PRINTED IN GREAT BRITAIN

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INTRODUCTION

The use of science to create new or better products and processes is among the most important of the economic objectives of the country. As consumers people have an interest in higher material standards of living; as producers, earning their living in a highly competitive international system, they have an interest in innovations which strengthen the country's trading position. This book contains some suggestions for policy and action by industry and by Government, which may assist in the fruitful application of science. We consider that British industry should first of all think of what it can do for itself, and not expect all its troubles to be eased by the balm of Government action. Therefore we first discuss action by industry—and it should be noted that some of our proposals could be applied to agriculture, commerce, and the service trades as well. But it would be foolish to deny that some of the conditions of technical progress must be created by Government action, and in Part II we examine a number of important aspects of public policy.

It is inevitable in writing on so general a matter that some of our proposals will seem to some of our readers to be elementary and obvious. We would assure such readers that the simple, elementary, and obvious things are not universally practised, and that we know of many who need to be reminded of them. The variety of circumstance in British industry is very great, and there is no mixture of policies which, like some magical compound fertilizer, will encourage the further growth in technique of small and large firms, firms using different processes and serving different markets, firms with a progressive tradition, and firms satisfied with parochial isolation. Every business-man and administrator has to think out what it is right to do in his own situation; our purpose can be no more than to guide and stimulate thought.

With this book, the third of a series, we complete the greater part of our work on the terms of reference of the Science and

Industry Committee, which was set up by the British Association for the Advancement of Science in 1952, and reconstituted with the additional sponsorship of the Royal Society of Arts and the Nuffield Foundation in 1954. These terms of reference had two parts: the analysis of what determines the speed of application of new scientific and technical knowledge in British industry; and the making of proposals for increasing that speed of application. We reported the broad conclusions of our analysis in *Industry and Technical Progress* (Oxford University Press, 1957), and some conclusions on the special question of decisions to spend money on capital equipment in *Investment in Innovation* (Oxford University Press, 1958). This book, by making proposals for action, rounds off the analysis, but we naturally find it necessary to refer back to the earlier works at a number of points.

The main evidence before the Committee was derived from the study of some 250 firms, spread over most of the principal industries, and of various sizes, forms of ownership, and degrees of progressiveness. The expense was largely met by grants from the Board of Trade and the Department of Scientific and Industrial Research, mostly under the Conditional Aid scheme for the use of counterpart funds derived from United States economic aid. But we have found it necessary to make supplementary studies in the preparation of this volume, and these have been supported by a generous grant from the Nuffield Foundation. We renew our grateful thanks for all these grants.

As authors of the three reports, we have been in a position of exceptional privilege; for we have had the help of a widely representative Committee of eminent men, who have nevertheless allowed us freedom to express our own views, regarding their own function as being to endorse the whole as worthy of publication. We have also been unusually fortunate in the quality of the staff we have been able to recruit, and in the ready assistance which we have universally received from industrialists and others. The names of all those who have been at any time members of the Committee, of its advisory group of accountants, and of its staff will be found on pages 182–3. We also record our thanks for the help given by our former Universities at Belfast and Keele, and by our colleagues in the academic world.

Those who wish to get a quick view of the scope of this book

will find in Chapter 16 an analysis of the suggestions made; and from these a selection can be made of those relevant to the circumstances of a particular firm.

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Stanley Jevons Professor of Political Economy
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Manchester, 1959

Part I

ACTION BY INDUSTRY

CHAPTER 1

Science and Technical Progress

EFFECTIVE action to speed up technical progress needs a framework of sound principle and a foundation in fact; therefore we begin by setting down briefly some of the ideas, principles, and facts which we consider that business-men should have in mind in reviewing the opportunities for technical progress in their firms.

The first point to be made is that technical progress does not always require the application of *new* scientific knowledge. There could be many new products and processes, and many general advances in productivity, even if there were no further progress in science. They would be created by the spread of *existing* technical knowledge, to firms which have hitherto been slow to pick up new ideas used elsewhere in their own industry, or across the shadowy boundaries of industries to firms which have seen the possibilities of ideas employed in other trades; or else they would be created by the use of *existing* fundamental knowledge to create a new technology.

This is obvious enough, but it has the important implication for some firms that the cheapest and quickest way to get technical progress may be to use knowledge which already exists. Sometimes this use is a matter of direct copying, but more often the ideas picked up by an alert management will not be in a form ready for use; they will need to be adapted, developed, tried out in new circumstances. Following what is now general usage, we call the activity of extending the bounds of knowledge *research*, and the activity of adapting an idea so that it serves the needs of full-scale production in a particular firm *development* (or, in certain engineering work, *design*). Such neat classifications, of course, seldom fit the complications of reality; there is a continuous progression from research undertaken without any expectation of commercial use (for instance, study of the characteristics of distant nebulæ) to development wholly

tied to an immediate commercial objective (for instance, the design of a new type of ornamental tail-fin for an American car). The following table explains some of the distinctions which can appropriately (though vaguely) be made:

Type of work	*Definition*	*Example*	*Typical places at which work is carried out*
1. *Basic Research*	Research on fundamental problems without any parcular intended application	Astronomical research; early atomic research	Universities
2. *Applied research*	Research undertaken having in mind a definite application:		
(a) *Background applied research*	Research increasing store of knowledge on which future applications can draw	Research on the properties of a raw material	Universities, Research Associations, sometimes industry
(b) *Product-directed or process-directed applied research*	Research intended to yield a product or process of given commercial characteristics	Search for new synthetic textiles, or new insecticides, or new steel production processes	Industry, Research Associations
3. *Development*	Adaptation of the store of existing knowledge to particular commercial circumstances	Design of a new power station, or a pilot plant for a new man-made fibre	Industry

The whole process which we call 'technical progress' involves the movement of an idea from its first discernible beginnings, often far from any possibility of application, to its successful commercial use. This may take a very long time—half a century would not be unusual. Some of the lapse of time is unavoidable, for an application may depend on progress in other industries (as the jet engine depended on progress in metallurgy), and it is too much to hope that all the relevant bits of knowledge will become available at the same instant. But there are other delays due to poor communication of ideas and the unwillingness to take trouble to understand them; and even if these obstacles could be removed, some delay might remain, caused by a poor deployment of resources at the different stages through which an idea must pass. Research creates a stock of ideas, like components in a warehouse, which development prepares for use. A country which regularly spends too little of its money and scientific man-power on development, and relatively too much on research, fills the warehouse to overflowing with ideas without achieving a high rate of technical progress. For a period a country can greatly increase its rate of technical progress by the intensive use of its existing component ideas; and, in a limited field, this is just what happens in war-time.

There is not enough information to enable us to appraise in detail the present deployment of resources in Britain, in which there is relatively more applied research and development than twenty-five years ago. But since development is an expensive process, often requiring much well-organized team work, there is always a danger that there will be too little of it. There is also a danger that, because of defects in communication, past developments will not be used to the full. The appropriate advice to firms seeking to make the best use of science in industry is: first, look for any neglected ideas already developed ready for use; second look for neglected ideas which can be made ready for use by an effort of development; third, look at those possibilities which require the creation of new knowledge as well as its development.

Industrial firms, as can be seen from the table above, sometimes undertake 'background' applied research, which is some distance from practical application but increases the store of knowledge on which future applications can draw. But this is a chancy business; it is possible to spend a great deal of money without finding anything which is relevant to the future operations of the firm. If the results were more predictable, one would expect to find large firms (at least) seeking to prepare the way for future progress by intensive background research. As it is, a survey in the United States in 1953 [1] recorded only about 4 per cent. of industrial research and development expenditure as 'basic research', which in this case must be interpreted as including our 'background' category. Our impression is that the proportion in the United Kingdom is no greater. It follows that a very important factor in industrial progress is the allocation of resources to the Universities and other institutions which, not being bound to commercial purposes, can take the risks of 'basic' and 'background' research.

Most of the effort by industry to provide new occasions of technical progress takes the form of product-directed or process-directed research or of development; but the intensity of the effort varies very greatly. The following table shows the variation between industries; the variation between individual firms is of course much greater.

[1] *Science and Engineering in American Industry*, Washington, D.C., National Science Foundation, 1955, table A.12.

Intensity of British Research and Development Effort, 1955

	Research and development expenditure as a proportion of the net output of the industry (%)	Proportion of all qualified scientists and engineers in the industry who are engaged in research or development (%)
Aircraft	35·1	84
Electrical engineering	6·8	62
Chemicals and allied trades	4·8	73
Precision instruments, jewellery, &c.	2·3	70
Non-electrical engineering and shipbuilding	1·8	41
'Other manufacturing'	1·8	61
Vehicles and components (not aircraft)	1·7	39
Bricks, pottery, glass, cement, &c.	1·0	75 (*a*)
Textiles	1·0	53 (*b*)
Metal manufacture	0·9	49
'Metal goods not elsewhere specified'	0·8	39
Leather, leather goods, and fur	0·6	(*b*)
Food, drink, and tobacco	0·6	66
Paper and printing	0·5	60 (*c*)
Manufactures of wood and cork	0·2	(*c*)
Clothing	0·1	28 (*d*)
All industries	3·5	60
All industries except aircraft	2·0	57

Source: Department of Scientific and Industrial Research, *Estimates of Resources Devoted to Scientific and Engineering Research and Development in British Manufacturing Industry, 1955*, H.M.S.O. 1958.

The industry totals conceal considerable variations between trades: e.g., expenditure as a proportion of net output was 0·2 per cent. in cotton spinning and doubling, 0·1 per cent. in woollen and worsted trades, but 4·1 per cent. in 'rayon, nylon, &c. and silk'. The aircraft industry in 1955 had a large amount of military and civil experimental work in hand.

Notes: (*a*) Apparently excluding bricks. (*b*) 'Textiles' and 'leather goods' taken together. (*c*) 'Paper and printing' and 'Manufactures of wood and cork' taken together. (*d*) The whole clothing industry is recorded as having employed fourteen scientists and engineers on research and development.

A table like this has a certain limited usefulness in giving a firm a first idea of the intensity of research and development effort in its industry, and also of the extent to which scientists and engineers are used in production—which, as we shall later suggest, is important for technical progress. But an *observed* difference in research and development effort is not necessarily a *desirable* one, and the factors which should determine the in-

tensity of effort in a particular firm are very various. We try to sort them out in Chapter 4, but it is appropriate to make a preliminary survey here, in order that we may emphasize the natural variety of response to the opportunities of progress in technique.

First it should be remembered that there are many purposes of research and development. They are well set out in a publication of the Standard Oil Company of California called *The Co-ordination of Motives, Men and Money in Industrial Research:* [1]

'Modern industry turns to research to accomplish the following objectives:

'To cure existing troubles and nuisances in connection with materials, processes, products and services, and to anticipate and prevent such troubles.

'To reduce the costs involved in the use of materials, processes, products and services.

'To improve the quality of existing materials, products and services.

'To reduce the consumer's operating and maintenance costs.

'To develop new uses for existing materials, products and processes.

'To develop suitable substitutes for existing materials, products, processes and services.

'To develop new materials, processes, products and services.

'To improve manufacturing techniques or processes.

'To make use of by-products otherwise wasted.

'To amass technical information leading to a better understanding of material, process, or product.

'To contribute to the common store of technical knowledge, with the ultimate motive of increased markets through better standards of living.'

These purposes are relevant to a differing extent at different times, in different trades, and in different sizes of firm. It follows that the profitability of research and development varies—it can be very high, or nothing at all. The evidence about average profitability is weak, and an average is in any case likely to be misleading. What is certain is that there are some trades (especially in science-based industries) in which research effort is immensely profitable. In a study of eight American chemical

[1] D. H. Voorhies, 1946.

companies, for instance, a research fellow at the University of Chicago found that \$1 spent on research caused an increase in productivity such that, after allowing for changes in capital and labour, output increased on the average by \$40.[1] High figures would probably also be found in the British chemical industry, and there are other industries where the profitability of research and development will become high as the basis on which applied research rests becomes stronger—that is to say, as a traditional or empirical attitude to production is replaced by a scientific attitude, and the necessary background knowledge about materials and processes is accumulated.

Differences in profitability therefore go some way towards explaining the differences in research and development effort shown in the table. The effort is greatest where a well-developed science or technology has a close bearing on the industry's products or processes, for then a discovery in the appropriate science may have an immediate and large effect on the firms in the industry; there will probably be a large amount of relevant basic scientific knowledge, and the normal processes of higher education will yield a supply of scientists capable of applying that knowledge in the industry. By contrast, industries whose technology is based on 'art' or traditional craft knowledge rather than science tend to give less attention to research and development. Applied research in such an industry is forced (for lack of basic scientific knowledge) to proceed by trial and error; this means that for a given expenditure it will probably not produce a large return of usable results. Science will appear to have less to offer to the unscientific.

The differences between the attitudes of industries are emphasized by differences in their recruitment of qualified scientists and technologists. An industry with little scientific basis will not employ many scientists; in consequence, it will have little knowledge of what science can do to change technology, and there will be barriers to the effective communication of new ideas—a matter which we discuss in Chapter 3. The industry will also have little capacity to adapt to its own needs technological developments occurring elsewhere.

Superimposed on all these differences are those which arise

[1] *Scientific Manpower*, Washington, D.C., National Science Foundation, 1958, p. 10.

quite naturally from differences in the size and nature of firms. A small firm is often necessarily parasitic on others, progressing by bringing in ideas which have been fully developed elsewhere (e.g., by a machine manufacturer). A large firm, at a particular stage in its existence, or even a whole industry, may appropriately be parasitic; it may, for instance, attain rapid technical change by bringing in fully developed ideas from overseas. Research, though in a sense the mainspring of technical progress, need not always be the first priority; we suggest in the next chapter other means of achieving progress which should be considered.

This explanation of variety serves as a warning against easy generalizations; but, although variety is the dominant impression when one looks at the research effort at a particular instant, the impression when one looks at a period of time is predominantly one of rapid advance. Expenditure in the industrial laboratories and development departments of Britain was one-thousandth of the national income in 1928, about one four-hundredth in 1938, and nearly one-hundredth in 1958—not a very large burden, but an impressive rate of increase, for the real national income itself has been rising. British research and development expenditure still appears to be growing fast, and we would expect it to grow even faster as more of the old-established industries find the scientific basis of their inherited crafts.

It can be argued that this growth of industrial research effort is not the only forward path—that, just as basic research is dealt with by institutions outside industry, so applied research and even development could become separate functions performed for a fee by specialist organizations. This would be a development of the present small beginnings of sponsored research organizations.[1] Dr. Reeves, Executive Vice-President of the Esso Research and Engineering Company, has written [2]:

'It seems evident to me that as time goes on a greater and greater share of our technology will be provided by independent research organisations not attached to specific industrial concerns. These independent research organisations, by competition amongst

[1] See *Industry and Technical Progress*, p. 39.

[2] E. D. Reeves, *The Future for Industrial Research*, in *Proceedings of the Ninth Annual Conference on the Administration of Research*, New York, New York University Press, 1956.

themselves, will establish the competitive market value of various forms of technology, and our present "captive" research organisations will remain in business only to the extent that they can compete with the independent groups and do an even better job.'

Dr. Reeves goes on to suggest that the development of such organizations will free trained scientists from the routine administrative work they are now doing in research and development departments and permit them to concentrate on truly creative activities. Other writers have stressed a different problem said to face scientists in industrial employment, namely that it 'will only be by chance that the almost irresistible lure of intellectual and inventive interest will coincide with the best judgements of what will most profit their firm', and that 'the formulation of "set" problems is destructive of discovery'.[1] Why, Professor Jewkes and his collaborators ask,[2] should it be supposed 'that the combining within one firm of the apparently incongruous functions of manufacture and the search for invention will contribute to the success of both'? Research, they argue, is always something of a gamble; there will always be a temptation in a manufacturing concern to direct the research from above, to limit the objectives, and to ignore the danger of assuming that the best way to organize manufacture is the best way to organize research; there will thus be a continuing tension between the interest of the scientist in freedom, and the interest of the firm in supporting only the profitable lines of research; and the research organization may itself become an obstacle to the rapid acceptance and assimilation of new ideas from outside.[3] The experts in a field are often blind to the opportunity of a radical new solution, while the 'outsider' is a frequent source of ideas for change.

This line of argument can be supported by reference to the many cases in which firms have been blind to the significance of inventions which are now clearly seen to be in their main line of interest; nevertheless we regard it as fallacious. The dangers of employing scientists and technologists on research and development *within* industry, rather than outside it, have

[1] Jewkes, Sawers, and Stillerman, *The Sources of Invention*, Macmillan, 1958, p. 134.

[2] Ibid., p. 129.

[3] Ibid., p. 143.

to be set against the advantages. At some stage a discovery has to be adapted to the needs of a particular market served by a particular firm; speedy technical progress in fact requires a consciousness of commercial objectives—otherwise time and resources may be 'wasted' (as far as industry is concerned) in doing things which are scientifically elegant, but which nobody really wants. This is a strong reason for having research within firms; and the tension which may certainly exist between research and production staff, caused by differences in their outlook, may turn out to be an asset rather than a liability. The research staff will have an interest in getting new technologies adopted; properly organized, they will be a pressure-group in favour of innovation; or, to put the matter another way, the tension between the scientific and the commercial attitudes can be the force which pulls the firm forward to better techniques and products.

In any case, modern scientific industry must employ scientists, and if scientists are employed in a firm they will be likely to build up research; they will not be satisfied with adapting other people's ideas. We do not deny that there will probably be some development of institutions specializing in research, but we think that this will go side by side with a further development of research within industry. Nevertheless, a firm should not try to be self-sufficient; blindness to new developments is more likely if it puts barriers in the way of the entry of new ideas.

Much industrial research benefits other firms, as well as the firm which pays for it. Thus chemical companies develop raw materials with new properties, which help other industries; the metallurgical industry develops new alloys; machine tool and equipment firms provide new machines ready for use. The technical progress of small firms, in particular, depends on their efficiency in acting as parasites, feeding themselves with the developments created elsewhere. An important factor in technical progress is therefore the effectiveness of liaison, the speed of communication of ideas from their creators to all potential users.

It follows that to make the best use of science in a world of changing technology, it is necessary to employ a good number of scientists and technologists on liaison and consultancy;

indeed, large firms need them as well as small. Efficient organization of the flow of information about science and technology will always be important. Documents are not enough; personal contact is needed. This is the problem which we take up in Chapter 3.

To sum up: technical progress involves the creation and the spreading of knowledge. One method of creation, namely research and development within industrial firms, has (for what we consider to be good reasons) been growing fast; though its content and extent will naturally vary greatly in different firms or trades. The potential growth is still great, both in industries which have newly discovered the scientific basis for their productive techniques and in industries which have still to explore the resources offered by science. The growth does not mean that a firm can be self-sufficient; important things are likely to be missed if it puts up a resistance to the entry of new ideas. Because scientific ideas can flow freely only between those capable of understanding them, scientific and technological staff can be usefully employed in small firms as well as large.

CHAPTER 2

The Relevant Management Techniques

THE last chapter shows how research expenditure has grown, and has come to be regarded as a principal means of achieving technical progress. But to praise the virtues of research is poor comfort to a firm too small to undertake it, and it may be inadequate and misleading in suggesting a course of action for a larger firm. The purpose of this chapter is to provide a reminder that research and development will make their full contribution to technical progress only if they are treated as two of a group of related management techniques.[1] The purpose of these techniques may be defined as the constant improvement of the relation between the input and the output of the firm. Such activities as *work study*, *production planning and control* (including quality control), *budgetary control and costing*, and *market research* are relevant; we discuss them separately below, but it is worth noting that the lines of division between them may become less marked because of developments in automatic data processing.[2] We also discuss in this chapter the related question of when a firm can use the 'technique' of development without undertaking research.

Why are such activities important to technical progress? Even if a firm already possesses research and development departments, their work may be wasted because poor market research and inefficient costing allow a bad choice of research projects. Inefficiency in production, which could be eliminated by work study and production planning, may cause the firm to be short of capital to support innovation. Because of lack of attention to training and recruitment (matters further considered in Chapter 8), a promising new process may be worked badly and give a poor yield, thus discrediting the efforts of the research and development departments. There are many such ways in

[1] See *Industry and Technical Progress*, Chapter 16, and C. F. Carter and B. R. Williams in *Journal of Industrial Economics*, March 1959.

[2] See John Diebold in *Automatic Data Processing*, Vol. I, No. 2, March 1959.

which the state of general efficiency throughout the management of the firm reacts back on the firm's progress in technique, and this reaction may remain important even if the firm does not support research and development of its own. A company which does not use at least some rudimentary forms of work study, costing, and production planning is often unable to use the research and development work of others, even when pressed to do so by Research Associations or by the suppliers of materials or equipment. Thus a firm which desires to innovate may need to start by giving attention to the general state of its management methods.[1]

Work study is the detailed analysis of methods so as to make the most effective use of plant, materials, and human effort. It is applicable to all kinds of mechanical and physical work, and it ranges from a simple analysis of what some more efficient firm does, to complex operational research. The objective of the work must first be carefully defined; then each element in it—the design and lay-out of equipment, the organization of labour, machine loading, material qualities, flows and stocks, &c.—is carefully examined to see if they lead to an economical achievement of the objective. Many firms have given information on the benefits derived from the technique.[2] Three pamphlets called *Notes on Work Study*, published by the Association of British Chemical Manufacturers,[3] describe how to introduce work study, and they include a list of organizations which give training in the technique.

In many medium and large firms work study has become a specialist and continuing function, which shows that the effectiveness of the method does not cease after one application. Work study often creates a demand for research and development, to solve the problems thrown into prominence by the work-study analysis, relating (for instance) to the design of plant and equipment or to the nature and control of materials and processes. A small firm may not be able to carry a work-study specialist, but it may be able to use consultants for an occasional review of procedure; and it can employ some of the

[1] See *Industry and Technical Progress*, p. 188, for a related point.

[2] A short and interesting account of the results of work study in various industries is given in *B.P.C. Case Studies: Work Study*, British Productivity Council, 21 Tothill Street, London, S.W.1, 1955.

[3] 86 Strand, London, W.C.2.

method (which has been described as a 'resolute application of common sense') in its normal management. Thus a systematic search of trade literature, such as is recommended in the next chapter in order that a firm may keep in touch with improvements in products or processes, is in itself a facet of work study.

Production planning and control is an allied technique, concerned with the economic completion of a pre-determined delivery programme. It is specially important where, due to the number and variety of the stages of manufacture, there is a difficult problem of co-ordination. This happens where a lot of components and materials are used for the product (as in motor-car assembly), or where the firm produces a lot of different products simultaneously or in series (as in most pottery factories, and many light engineering works). Production planning systematically analyses this problem of co-ordination, and identifies the 'bottlenecks' or places where the different elements of the productive process are not properly related to one another. It often leads on to work study, e.g., on such matters as plant lay-out.[1]

Having set up a productive process so co-ordinated that it ought to work smoothly, the firm must see that it does in fact do so. Plans can easily be disrupted because of undetected variations in raw materials, in process conditions, or in machine operations; the firm needs to keep inputs and outputs to the desired standard of quality, and to have a system for identifying and isolating or rejecting sub-standard raw materials, components, machines, and products. In some industries this involves laboratories for testing—and research work often grows out of the work of the testing laboratory. But it often happens that neither the laboratory, nor measuring devices on the shop-floor, can test every item—the numbers are too great, or testing is impossible without the destruction of the goods tested. If sampling is used, it should be used systematically under a system of statistical 'quality control', so that small variations due to chance (for which no corrective action is needed) can quickly

[1] *Better Ways*, published by the British Productivity Council, 21 Tothill St., London, S.W.1, provides a useful short description of this and other management techniques; and the British Institute of Management, 80 Fetter Lane, London, E.C.4, will offer further advice. Concentrated courses on production planning and control are available in London, Birmingham, Glasgow, and other centres.

be distinguished from a decline of standards or a breakdown in the process. Complex problems of production programming and stock control require highly trained (and very scarce) statisticians for their solution. There are, however, simple techniques capable of application in small firms by people with little training in statistics. It is important that firms should learn these techniques; a local technical college may be able to assist in providing the necessary training.

Budgetary control implies that the plan of operations is based on forecasts of sales, income, and expenditure. Departmental budgets are constructed and used to help executives to keep to the requirements of policy. The continuous comparison of actual with budgeted results suggests when special action is needed to secure the objectives of policy, or how the policy itself may be revised. The technique is appropriate when the chain of management command is so long that those at the top need to decentralize responsibility, while still centralizing control. Firms which are small or simple in their structure, without much differentiation of grades of management, need the technique only in a simple form.[1]

Budgetary control implies *costing*; so also does effective work study. Costing may be defined as a means of recording and presenting information about the costs of products, processes, and operations in such a way that the records are a useful method of management and a means of control. Only with good costing is it possible to compare the efficiency of old and new processes and to identify reasons for differing degrees of efficiency between departments and firms. We showed in *Industry and Technical Progress* (p. 210) that the absence of costing was a significant factor in explaining the slow introduction of the tunnel oven in the pottery industry. The following remarkable figures, supplied by a pottery firm which has made big changes in its methods, show how far mere guesswork about costs can depart from the reality:[2]

[1] This subject lies in the field of the Institute of Cost and Works Accountants, 63 Portland Place, London, W.1, which publishes a useful *Introduction to Budgetary Control, Standard Costing, Material Control and Production Control*. The Institute of Chartered Accountants in England and Wales, Moorgate Place, London, E.C.2, publishes a pamphlet on *Management Accounting*.

[2] B. R. Williams in *The Structure of British Industry*, ed. D. Burn, Cambridge University Press, 1958, Vol. 2, p. 316.

	'Guesswork' calculations of costs (£ per annum)		Actual costs (£ per annum)	
	Bottle oven	Tunnel kiln	Bottle oven	Tunnel kiln
Fuel	21,000	19,500	7,000	6,500
Other items . . .	5,000	3,500	19,000	12,000
Total . . .	26,000	23,000	26,000	18,500
Saving (by change to tunnel kiln) . .	3,000		7,500	

Market research is concerned with finding out where a market for a product exists, what it will absorb, what modifications of the product or changes in its price will make it possible to sell more or to realize higher profits, and what channels and methods of distribution are most appropriate. It may involve expert statistical work and highly skilled field interviewing; it must always be regarded as a systematic appraisal of the needs of customers and potential customers, and not a mere collection of guesses from salesmen. We have noted in our inquiries many firms whose market research is rudimentary or non-existent—firms which rely on existing trade contacts, but make little effort to find out what customers really want. This 'take it or leave it' attitude is often associated with technical backwardness, and it may be necessary to begin the process of stimulation, not by setting up laboratory research for a purpose which is still vague, but by using market research to give precision and realism to the aims of the firm.

A firm which is conscious of a need for technical progress should, we think, review its use of the various management techniques which we have discussed. It may thus obtain a big improvement in the relation between 'input' and 'output', without spending a lot of money on laboratory research. Consultants can readily be found [1] to advise on the introduction of new management techniques, and also on the absorption into the firm of established technological practices. The consequent possibility of progress is especially important for firms too small to undertake innovation on their own account. Such firms progress by being efficient in their organization and by being keen to pick up and use developed ideas and techniques from elsewhere.

[1] The British Institute of Management maintains a register of consultants.

In larger firms (and in quite small firms in science-based trades such as drug manufacture or electronics) the pursuit of management efficiency may point to a need for the more complex management techniques of development and research. When can such firms confine their 'innovatory activity' to development or design (using existing scientific and engineering knowledge), and when must they engage in research as well?

The answer to this question varies with the type of innovation planned and with the size of the firm. Certain innovations are planned before there is sufficient scientific and engineering knowledge for their development, and therefore necessarily involve research. This was so when the Government first sought to create atomic power-stations; the Atomic Energy Authority had to do much preliminary research. When in 1918 the Tootal Broadhurst Lee Company set out to find a crease-resisting treatment for cotton cloth, the scientific background to their quest was so hazy that research was a precondition of development. The new float process for producing glass, developed by Pilkington Brothers Ltd., involved such a radical change that considerable background research was essential; the starting-point for the chemical method for producing penicillin, developed recently by the Beecham Research Laboratories, was a general programme of research designed to find a penicillin 'nucleus', to explain F. P. Doyle's observation that a penicillin-exhausted mould fermentation brew produced further penicillin-like activity when chemically treated.

In most firms innovations are not planned from the pre-development stage in this way, though of course a good many innovations come up against particular problems during development which need further bits of research to solve them. Can the firm avoid tackling these bits of research? It may be able to put them out to a Research Association or Institute, or to a University department. Indeed, it may have to do this, because it does not have the amount or the type of research staff and research facilities required. Here one of the important factors is size: research departments are rare in small firms, and even in large and medium-sized firms (outside the science-based industries) it is unusual to find research departments capable of undertak-

ing basic or background research, as opposed to research which is product-directed or process-directed.[1]

Development and design are complex matters. Sometimes they involve (as in the chemical industry) the 'scaling up' of a process proved to be promising in the laboratory, so that it suits factory conditions. Sometimes (as in engineering) they mean taking an idea which looks good on the drawing-board and testing it out in a trial model. Sometimes they involve adapting for one process a method already proved serviceable for another. During the development period, new cost and market data are commonly accumulated, and it becomes increasingly possible to tell whether an idea good in principle is going to be a good business proposition. If a firm is thinking that it may be able to confine its innovatory activity to development, there are three basic questions which it should answer:

1. Are the development problems likely to be comfortably within the limits of existing scientific knowledge, or will they strain against them? If the latter, is there an Institute or University to which the firm could turn for research help if need arises? If there is not, the development project is clearly a very risky one. It would be unwise to undertake it unless the expenditure was small (and the potential return great) in relation to the available resources of the firm.

2. Is the development itself likely to be within the capacity of the firm? Does the firm possess the technical capacity (or the 'knowhow') required? (Here there is a clear distinction in (e.g.) a pottery firm between introducing a new body or a new glaze, which call for the firm's own type of specialist knowledge, and introducing new ovens, which have customarily been designed and built outside the pottery industry; similarly in a paper firm there is a difference between developing a new type of paper and creating a new and complex paper-making machine.) If the firm has the technical capacity for the development, has it the managerial and financial capacity? In particular, can it afford to meet not only the likely cost of the development but also the cost of creating the appropriate productive and

[1] Some large firms in the chemical and electrical industries do, however, set aside a small percentage of their research and development budget for basic or speculative research.

marketing capacity if the development succeeds? Unless the firm can finance not only the development but also its application (whether from its own or from borrowed money), then it should proceed with the project only if it hopes to get a satisfactory income from royalties.[1] In Chapter 4 we discuss in further detail the appropriate principles which should guide investment in both research and development.

3. If the development is not within the technical capacity of the firm, can the appropriate help be gained from other firms? There are two main cases to be considered, which can be made clear by a few examples. In the first type of case the firm that is planning a process or product development approaches specific firms for assistance. Thus a paper firm was able to develop wet-strength paper because one of the chemical firms approached was able to supply the particular kind of resin required; a pottery firm producing cast ware was able to develop equipment for the production of 'slip' of consistent density and fluidity, and also automatic casting machines, by getting the co-operation of the machinery makers; a maker of cutlery, having worked out the nature of a required process, was able to interest a machine-tool manufacturer who made a striking new machine. In such cases a firm, before starting work on development, can discover whether the suppliers of materials or machinery are prepared to co-operate. Sometimes the other firms may regard the suggestion as being little more practical than a request for a perpetual-motion machine. But even if the other firms regard the suggested development as feasible, difficulties may later arise. Firms originally prepared to co-operate may lose interest, for instance if the cost of developing a new machine turns out to be very high in relation to the potential market; or they may simply lack the capacity to produce the appropriate new machine or material. There may also be unexpected problems, the solution of which needs the co-operation of firms not originally involved—as happened in the development of the Whittle jet engine, when Firth Vickers developed a new nickel-chrome alloy to avoid failure in the turbine blades.

In the second type of case the firm which is planning an innovation may be dependent on many firms which cannot effec-

[1] As in fact the Calico Printers Association has done from licensing its invention 'Terylene'.

tively be approached in the pre-development stage. This happens if a firm is trying to invent a product (e.g., a machine) which will be a *process* innovation in other firms. Often such a product cannot be perfected without full-scale trials under factory conditions, and success will often depend on finding a firm or firms prepared to undertake (and perhaps to help to finance) such trials. This happened in the development of the tunnel oven in the pottery industry (which was impeded by the failure of potters to co-operate with suppliers) [1] and in the development of the Raper Auto-leveller in the textile industry (which was helped because facilities for mill trials were made available).[2]

These kinds of co-operation in development may involve a whole chain of firms; and this is one reason why even a firm which does no development of its own can by wide-awake and efficient management play an important part in making innovation possible. Thus if there were fewer parochial firms, machinery suppliers would be less likely to find innovation unprofitable.[3] The impetus to development need not come from the heavyweights of industry. It is quite possible for small firms to take the initiative in using new machines or new automatic controls, or in approaching machinery makers with suggestions for improvement. They may not be innovators themselves, but they encourage innovation by others.

But this brings us back where we started, for the wide-awake management which encourages innovation in others is a management strengthened and informed by sound techniques of control. Thus to the individual firm we would say: Check the adequacy of your management techniques. If they are rightly chosen and well organized they will themselves show you the way of progress, and will reveal whether there is a need for development or research. If such a need exists, later chapters suggest how the work may be organized. But first we discuss a matter which might be regarded as a management technique in its own right, namely the technique of keeping in touch with the outside world.

[1] *Industry and Technical Progress*, p. 209.
[2] Ibid., p. 73.
[3] Ibid., pp. 112–14.

CHAPTER 3

The Communication of Ideas

WHETHER a firm is seeking to improve its efficiency by copying the practices of others, or whether it is trying to innovate, it is very important that it should be open to receive new ideas and new knowledge. It is too narrow to conceive this as a process of communicating the results of basic research (done, for instance, in universities) to those who will develop and apply them. The communication of knowledge about fully developed processes, from one firm to another in any industry, or from one country to another, or from a supplier of machinery or plant to his actual or potential customers, is equally important. So is the communication of methods of running a business, for instance the management techniques mentioned in the last chapter; or of half-formed ideas of things worth the attention of research workers or designers; or of ideas about possible markets or methods of distribution. Hence we have given this chapter a completely general title.

It is important not to conceive of communication solely as the passing of neatly packaged pieces of information to fulfil a well-defined need of the recipient. Many considerable technical advances are the unexpected outcome of a convergence of ideas from different sciences or technologies. This means that they contain a chance element, but they need not be left wholly to chance, for something can be done to increase the probability of a useful interaction of ideas (as we suggest below). There is therefore a need to make sure of a free flow of ideas from varied sources; many will prove useless, but a few will take part in a highly profitable reaction.

The problem of communication can be analysed in many ways. It is a problem of *selection*, for the variety of ideas which might usefully impinge upon even the narrowest section of technology is very great, and even the largest firms cannot keep in touch with everything that might be relevant. They must select

what seems most relevant, and this is a difficult exercise of judgement. The problem is one of '*language*', not only in the obvious sense that much new knowledge is written up in foreign languages which the insular British do not like to learn, or have no facilities for learning, but also in the sense that different branches of science develop their own jargon, which is understood only by the initiated. The problem is one of *organization*, in that the mass of material to be dealt with is so great that even with expert librarians and abstractors it is difficult to find a particular bit of information with speed and certainty. Finally, communication involves not merely the organization of the passage of selected and translated ideas, but also human beings at each end, who are occasionally unwilling to give information and frequently unwilling to receive it; the problem can therefore be regarded as *psychological*.

As might be expected, the formal, organizational problems have had the most attention. In the communication of ideas between specialists in the same field, that is between people who can in principle understand each other easily, the main problems are the amount of written material and the fact that it may appear in a language unknown to the reader. The world's annual output of scientific and technical literature doubled between 1945 and 1955, and may double again over seven years. Elaborate abstracting services have been set up, sometimes centralized (as in the U.S.S.R.), sometimes run by a range of specialist and local organizations; but international co-operation still has a long way to go. There is much duplication and there are many gaps. Translation problems are at their most acute in relation to the vast Russian scientific output, and here there is Anglo-American co-operation to avoid duplication of effort. But even if complete abstracts in standard languages were available, the problem of indexing and of finding things quickly remains formidable. The capacity and speed of electronic computers may provide an answer, and there have also been experiments with computers to provide automatic translation. Yet the most elaborate and highly mechanized services will never be perfect, if only because an abstract can seldom be perfect; it can state what is relevant in scientific literature only in relation to some idea of the needs of the users, and these are seldom fully known.

In the communication of ideas between specialists in different fields—for instance, from an atomic physicist to an organic chemist—the same difficulties appear, but they are formidably augmented by the fact that a much smaller common basis of knowledge can be assumed. The argument, if it is to be understood, has to go back nearer to 'first principles', and it must not assume much familiarity with other literature in the specialized field. It is true that a common understanding of ways of getting information can be assumed; the organic chemist will not know the books or journals in which the results of atomic physics appear, but he will probably be well able to find out about them by intelligent questioning. But the barriers to effective communication are very great, and consequently cross-fertilization between specialist subjects often depends on the chance existence of a 'double specialist'—a person with considerable knowledge of both subjects.

An example of such a person making an imaginative combination of his varieties of knowledge was C. R. Burch of the Metropolitan Vickers Electrical Co. Ltd. He was interested in the deterioration of high-grade mineral insulating oils, and was investigating the 'degassing' taking place during the processing, by the application of heat, of a large quantity of deteriorated oil. Distillation had always interested him, and he chose to distil under a high vacuum. 'No chemist [he wrote] knows how to make a vacuum and no vacuum worker has been interested in distillation, except Hevesy, and he has not applied molecular distillation to organic chemistry. It would be rather jolly to distil mineral oil under really high vacuum.' Burch's work led to low-vapour-pressure oils, which in turn contributed to the development of very efficient vacuum pumps and to large demountable valves and X-ray tubes; these in turn contributed to progress in nuclear and sub-nuclear physics, for when Cockcroft and Walton disintegrated the lithium nucleus they used a Burch pump and a demountable high-voltage proton-accelerating assembly.[1]

The communication of ideas from a specialist in science or technology to an intelligent non-scientist—say, from a research director to a managing director—is obviously still more diffi-

[1] See Willis Jackson, *The Research Project—Choice and Termination*, in *The Direction of Research Establishments*, (National Physical Laboratory), H.M.S.O., 1957.

cult. It requires a good appreciation of what the non-scientist can be expected to understand, and the specialist will often feel that he can make himself understood only by a misleading degree of simplification. Fortunately it may not be necessary, in this kind of communication, to convey an understanding of all the technical detail; the important thing may be to convince the non-scientist of the value of the result (or to make him feel that further inquiry is worth while) and to show him what costs and what changes of organization will be involved. At this level the effectiveness of communication depends greatly on skill of presentation and on the readiness of the non-scientist to 'open his mind' to new ideas. The information may have to be conveyed in a way which not only instructs but also persuades; at this point the problem of communication merges into that of propaganda. The difficulties take a similar form where ideas have to be communicated to people of limited education and perhaps of no great intelligence—e.g., in introducing a craftsman to a new process or a new material. This is often a matter of conveying minimum information about what has to be done, without assuming any background of knowledge of why it has to be done (though if reasons can be given in a clear enough form, so much the better); and skill of presentation is of great importance.

What guidance does this analysis offer for the policy of firms? We suggest five points:

1. Since communication is easiest between specialists in the same field, the receptiveness of firms can be increased if they employ scientists and technologists in greater numbers and from more varied fields of interest.

2. People who are expert in more than one field are especially valuable; they are hard to obtain, but something can be done to train them, or (failing this) to make sure that opportunities of 'cross fertilization' between experts in different disciplines exist.

3. Personal contact is likely to be more effective than written communication; it is more difficult to ignore, and there is a chance of asking questions and clearing up obscurities immediately.

4. Effective communication is a technique which does not

come by accident; such things as the right use of technical journals and abstracts, indexing, the proper exploitation of library and research institution resources, and the writing of clear technical reports and instructions have to be learnt. This means that particular people must be assigned the task of learning the various techniques.

5. The principles which apply to the communication of science and technology can be extended to cover the communication of management techniques, such as those discussed in the last chapter.

A firm which wishes to assure itself that it is open to receive new ideas should, we think, begin by making a check-list of the fields in which the communication of ideas may be important to its progress. These will obviously include the technologies directly applied in the firm's present processes, and the basic scientific knowledge which lies behind these technologies; and they will also include management and sales techniques. There will, however, be other fields, perhaps of marginal importance only to the firm's present operations, but significant as being the places in which future change may be initiated. Thus the study of the properties of the firm's materials, or of alternative materials which might be used; or the study of rival or substitute products, to assess their precise advantages and disadvantages and the ways in which their competitive power may change; or the study of general techniques not yet applied in the trade, such as automatic control devices or the application of computers—any of these may turn out to contain essential growing-points for the future.

Such a check-list can be helpful to a small firm as well as to a large one, though a small firm will have to recognize its need to depend on others (e.g., on research associations or suppliers of machinery) to communicate ideas in an easily assimilated form. But even a small firm has to take some initiative—joining the relevant research association or welcoming the technical staff of machine suppliers. It is no use expecting ideas to be served up like a tasty meal to tempt the appetite of the unwilling.

The next point for a firm to consider is how far its receptiveness to new ideas can be assured by employing the relevant

specialists. A firm which employs a specialist for the first time is replacing the difficult line of communication from an outside specialist to a layman by two lines of lower resistance—from specialist to specialist, and by personal contact from specialist to layman within the same firm. The improvement in speed and certainty of the communication of ideas is an important subsidiary benefit, a valuable by-product, from the employment of scientists and technologists, and also of statisticians and of experts in management techniques. In a firm too small to justify the employment of such specialists in technical departments (research, work study, &c.), it may nevertheless be worth while to do something to improve the proportion of managers with a scientific background. People sometimes deplore the 'loss' of scientists to management jobs—'He's just an administrator now'—but the improvement of the receptiveness of management is a considerable benefit to be set on the other side.

At this point the firm should consider whether the range of interests covered by the specialists is really sufficient, and whether the opportunities of 'cross-fertilization' exist. Some 'cross-fertilization' will occur because an unsolved problem brings into prominence the need for the knowledge of the techniques or principles of another science; there will be a deliberate effort to extend the range of expert knowledge available to the firm sufficiently to find the solution to the problem. The more difficult problem is to increase the probability of a valuable *chance* convergence of ideas. In a large firm a trained information officer, whose job it is to have a general knowledge of what is interesting in several fields, can give valuable help. In a smaller firm special training schemes to give technical staff access to new fields of knowledge are worth considering; for instance, a man who has been through a good work-study course, or who has studied the varied uses of radio-isotopes, is likely to find a creative reaction on his normal work. A firm should consider whether the occasions of contact between staff of different interests are sufficient; for instance, the practice of siting research laboratories in pleasant country houses, far away from any of the company's factories, can be harmful, because it limits contact between research staff and those who are struggling with the problems of production, testing, and sales.[1]

[1] But see p. 55.

Having employed specialists, it is important not to block their effectiveness as channels of communication. Therefore we find that technically progressive firms take scientific journals of good quality, and provide (if they are large enough) an elaborate library service; smaller firms maintain good contacts with technical libraries, a matter on which we have more to say below. Progressive firms also commonly encourage the attendance of members of their staff at conferences and meetings of learned societies, where (even if the subject for discussion is not relevant to the firm's interests) the personal contact with specialists in the same field may be fruitful. This process of personal communication is made easier if the firm is not secretive about its own activities. On the whole, we find that it is backward and parochial firms which are most secretive on technical matters—sometimes secretive about things which are perfectly well known to their competitors. Progressive firms often find their protection in their ability to keep ahead of their competitors; that is, they trust, not their own secretiveness, but the slowness of others in copying them; they are sometimes remarkably ready to throw open their factories to visits by competitors, and to allow their staff to contribute to journals or conferences. The protection of patents makes such an 'open' policy easier (once the patent is granted), but we do not think that it explains it fully.

Few firms are able to employ specialists in all the fields which may be of interest for the future progress of the firm. Some of the communication of ideas (and a large part for small firms) must depend on the action of laymen, or of specialists in a different field, in following up hints of promising ideas and finding those who can offer technical advice about them. This survey of possibilities needs to be regular and deliberate, a planned activity, even if it can amount to no more than a study of trade circulars from machinery suppliers.

The problem in planning such an activity is the mass of material which may be relevant. Any firm which sets out to buy all the relevant journals will soon discover that their number runs into hundreds or thousands. For scientific work, time can be saved by using the abstracting services, but even so, the number of possibilities will remain large, and the quality and coverage of abstracts is not always good. In dealing with written communication, therefore, the emphasis should be on quality

rather than sheer bulk, and it is worth while to get the best possible advice about the material which should be taken. The emphasis on quality does not mean that only 'highbrow' journals should be taken. Many trade journals, reporting on interesting developments in their industry, provide just the simple non-technical outline which can show if an idea is of interest, and show where further information about it can be found. Even chance references in the daily Press have 'sparked off' important developments.

A systematic way of dealing with this problem is to make another check-list of the types of written communication which are relevant in the various fields of interest which are important to the progress of the firm. The contents of this list will, of course, depend on the size of firm and the type of industry, but it should begin by covering the appropriate pure science journals (e.g., the *Proceedings of the Royal Society*), the abstracts, the research-association and research-laboratory journals and technical bulletins, the 'discussion journals' (e.g., *Nature*), the technical journals on specific subjects, and the general trade journals and reviews. Having thus accumulated a list which is probably much too long, it can be examined systematically so as to cut out the sources of minor relevance or poor quality in each class, until a list appropriate to the size and resources of the firm is obtained.

But this is not the end of the matter. Two more questions must be asked. First, is the written material obtained used to the best advantage, or is it locked up in the research director's room? There may be need for a works librarian, or for an information officer, or for a new system for circulating relevant papers. The common form of circulation system, which is a sluggish flow of a great mass of undifferentiated material to a group of top executives who are too busy to read it, is highly inefficient. Is it, perhaps, worth employing someone in the firm to do some preliminary indexing or abstracting, so that circulated papers can bear 'signals' showing what is specially relevant? The most important journals should perhaps have additional library copies which are always available; it is a common experience to find that vital recent information has got lost somewhere in the circulation system.

From all this there emerges a plan and a budget for written

information. The second point for consideration is whether this budget is in right relation to what is spent on personal contact. Is time set aside for visits from research-association information officers, and for visits to the association's laboratories? Are members of staff encouraged to go, at the firm's expense, to scientific and technical conferences, where they may pick up ideas? Are there enough opportunities for discussions within the firm? In 1957 the Los Angeles Chamber of Commerce made a survey of ideas for relieving the shortage of engineers. There were many suggestions for improving the quality of engineering output, and opportunities of personal contact were frequent among these.

> 'Maximum participation by all engineers in the work of the local engineering societies should be encouraged. . . . More engineers should be sent to national policymaking conferences. . . . Sound management-engineer communications programs are encouraged with special emphasis on panel meetings, conferences, clinics, symposia and seminars. . . . Regular brainstorming sessions should be conducted on exclusively engineering subjects. . . .' [1]

We would like to stress the need for firms to set themselves a conscious high standard of reaching out and pulling in the information which they need. A large firm should, we think, normally provide for extensive world-wide travel by some of its executives, so that it is conscious of the best standards of technical progress set anywhere in the world; small firms should at least be conscious of (and interested in) the best practice in the United Kingdom, and should if possible provide for occasional overseas visits. Firms of all sizes, to the extent that their resources allow, should have good high-level contacts with specialists in the technologies in which they are concerned.

For both written and personal communication, much help can be obtained from outside. Thus, something might be gained if more firms made intelligent use of local library facilities. It is not sufficiently realized that local libraries have access, through the system of inter-library loans, to vastly more books and periodicals than they can house themselves. In some areas local associations of technical and industrial libraries have been

[1] David C. Greenwood, *Solving the Scientist Shortage:* Washington, Public Affairs Press, 1958, pp. 49–52.

formed; and in due course the National Science Library, to be set up at a site in Yorkshire, will provide an international collection for scientific reference better than anything hitherto seen. Local librarians are usually (in our experience) anxious to display the resources of the library movement, and will take much trouble to find a person competent to answer the queries of industry.

Part of the justification for having research associations, supported in part by public funds, is that they should be able to provide information and advice for firms too small to support research facilities of their own. Yet many research associations report that it is the large firms which already possess research departments which are the chief source of queries, and that a good deal of trouble and expense have to be spent to awaken the interest of smaller firms in the services for which they have subscribed. We later discuss [1] measures which might be taken on the research association side; but we think that all firms should from time to time consider whether they belong to the relevant research associations, and whether they are making full use of the information and research services provided. These services may include the running of short courses about new technical developments, and the provision of work-study teams. Similarly, firms should consider whether they are making adequate use of any local associations which provide information and technical advice services. There have been interesting recent developments in such local services; an example is the Birmingham Productivity Association Technical Advisory Service, set up in 1956. During 1957 this service dealt with 100 inquiries, and during 1958 with 396; in nearly all cases it was able to give the information or help sought, either by finding an existing source of help or by calling on the services of a panel of experts. A comment sent to us by a member of the staff of the Service underlines the value of personal contact and the need for more initiative by firms: 'Our experience has shown that even a free service must be "sold", and a high proportion of the time of the staff has been spent visiting firms and telling them what can be offered. As soon as this process of visiting is reduced the number of enquiries falls, so that continuous effort has to be made.' We understand that, following

[1] P. 116.

an important survey of the problems of smaller engineering firms made by the Scottish Council in 1956, a similar liaison service has been set up in Glasgow, based on the Royal College of Science and Technology. A survey was also carried out in 1956 by Professor W. E. Curtis, F.R.S., on behalf of the North-East Industrial and Development Association, which suggested that some 400 firms in the north-east area would welcome a technical information and advice service. Such a service, helped by the local technical libraries, has recently started work. Groups of firms in other areas would do well to copy these examples.

Firms should also consider whether they have sufficiently developed their contacts with university and technical-college staff who might be willing to help; and whether they can make use of sponsored research institutes, technical consultants, or management consultants to deal with particular problems.

A corollary of the readiness to look out for ideas is a readiness to adopt ideas which come from outside on their merits, without giving any priority to those developed within the firm. The 'willingness to be parasitic' is an important characteristic of technically progressive firms. It means, in particular, that such firms are willing to take new knowledge on licence from other companies, or to enter joint ventures. The importance of licensing agreements as a means of communicating technical knowledge from advanced countries may be judged by a report [1] that in 1957 United States companies received $238 million in royalties and similar payments from overseas subsidiaries, and $140 million from other overseas concerns (mostly in Britain and Western Europe); the traffic in the other direction was worth only $22 million, but no doubt there are (as additions to both sides of the account) agreements for the exchange or pooling of technical information without payment of royalties. It is possible that new ideas flow more easily through a maze of international channels than they can hope to do between firms which are direct competitors in the same market; and a willingness to examine what is happening overseas is therefore of the utmost importance.

Special attention may be needed to ensure a free flow of the kind of technological 'knowhow' which does not find a place in systematic literature, but travels by word of mouth, or is car-

[1] *Financial Times*, 9 January 1959.

ried by staff who move to other industries or firms. Specialist contractors and machine suppliers, who have seen problems repeat themselves in the factories of several customers, are often valuable as carriers of 'knowhow', and their advice should be fully used.

If a firm is of small size or has limited resources (e.g., of scientists and technologists) it can hardly expect to 'see developments coming' by watching what is happening in fundamental research; the scope of its inquiries will tend to be limited to the results of development, and among these to developments which are on its main line of interest. It would be unfortunate, however, if this meant a neglect of advances which are just about to 'break in' from other fields of technology. From time to time it is desirable to return to the check-list of potential fields of interest, to bring it up to date and to ensure (perhaps by the use of consultants or special advisers) that marginal fields are not wholly neglected.

The problem of the communication of ideas exists within a firm as well as in its links with the outside world. Here it merges into the general problems of management; the creation of a team spirit, the specification of responsibility and authority and of the objectives of the company, the prevention of misunderstanding and delay. If scientists are regarded as a peculiar race, not part of the social system of the company, they may be effective as receivers of ideas but not as transmitters to those in authority. Effective internal communication of technical ideas is made easier if there are people in production departments and in top management who have at least some scientific or technological background. British industry employs far more of its scientists and engineers *within specialist departments* than American industry does; we think that this concentration is sometimes a source of weakness.[1]

[1] The problem of communication discussed in this chapter is, of course, worldwide; it is seen through Russian eyes in an article by A. Topchiev, 'Chemical Science—at the service of socialist productivity', *Kommunist*, June 1958, 43–50 (trans. D.S.I.R.). Dr. Topchiev comments:

> 'Work is . . . slowed down because, as a result of insufficient coordination of scientific work, there is a certain amount of parallelism—there is a lack of purpose, and no tendency to solve the main problem. We must make sure that there is much more thorough and operative coordination in the work of the institutes of the U.S.S.R. Academy of Sciences both between themselves and with the

> scientific academies of the federated republics, with affiliated Academies, technical colleges and other scientific institutions of our country. The main fault continues to be lack of the necessary contact between the institutes of the U.S.S.R. Academy of Sciences and the affiliated industrial institutes, as well as the incomplete, often fortuitous, nature of their relations with manufacturing concerns. . . . Naturally, gaps in the organisation of the information service are also reflected in the productivity of our scientists.'

He refers later to the need for the active participation of industrial concerns in technical development and in the introduction of new processes, and for close team-work between scientists and industrial workers. It is clear that the U.S.S.R. is conscious of a problem of communicating ideas to its industrial managements.

CHAPTER 4

Research and Development Decisions in Larger Firms

THIS chapter and the next are addressed primarily to firms which are unquestionably large enough to undertake their own research and development, and it is based on a study of companies which seem to us to be effective in innovation. In this chapter we discuss the choice of research and development projects, and the fixing of a research budget, and in Chapter 5 the management of the projects once they are under way. Although we examine the problems of innovation in small firms separately in Chapter 6, some of the general principles suggested in this chapter are relevant for firms of any size.

The outputs of a research department consist of ideas and fundamental information (e.g., on the properties of materials); these are inputs for the development department, which in turn has an output of prototypes or designs. The output of the development department, and some of the output of research, provide inputs for the production departments. Since the aim of nearly all firms is to produce *things*, and not just ideas, the proper purpose of research and development is to provide good input-value for the production process. Industrial research and development should not have as its aim the exploration of the wonders of Nature or the conduct of experiments which are scientifically interesting and beautiful. These will often be valued by-products, but the main object of the work (if it is to earn continued support from industry) is as a management technique for furthering the chief productive purposes of the firm.

This statement, however, conceals difficulties. How does one define the 'productive purposes' of the firm? And, since research and development are chancy activities, which cannot usually be planned to yield a given result with certainty,

how is their disorderly behaviour to be brought under control?

In *The Changing Culture of the Factory*[1] Jaques gives an account of the purposes of a company which has given considerable attention to the conditions of operating efficiency and stability. The purpose of this company is defined as 'the continuity and expansion of a working community, the conditions of which will enable its members to serve society, to serve their dependants, to serve each other, and to achieve a sense of creative satisfaction. This purpose will best be accomplished by:

1. Seeking the maximum technical efficiency.
2. Seeking the utmost possible organizational efficiency.
3. Seeking to establish an increasingly democratic government of the Company community, which will award fair responsibilities, rights, and opportunities to all its members, consumers, and shareholders.
4. Seeking at all times to earn such revenue that the Company will be able—

    (*a*) To provide such reasonable dividends for its shareholders as represent a fair return on their capital investment for the speculative risk incurred.

    (*b*) To undertake research and development in order to enable the Company to attain a high position in the competitive market.

    (*c*) To provide those who work in the Company with working conditions which will promote their physical and mental well-being.

    (*d*) To improve its equipment to enable those who work in the Company to do so with the greatest possible effectiveness.

    (*e*) To raise wages and salaries in order that those who work in the Company will be able to live full and happy lives.

    (*f*) To improve the Company's service to its customers by reducing the price or improving the quality of its products.

    (*g*) To make reserves to safeguard the Company and those who work in it.'

[1] Tavistock Publications, 1951, p. 332.

Many companies would probably accept this as a statement of objectives, though often with reservations about paragraph 3. The list can be extended; for instance, it may be important to earn such revenue, and make such distributions to shareholders, as will put the firm in a position to attract fresh capital when it is needed. But the statement of objectives, if one looks at it more closely, is like an election address—it proposes to undertake what is desirable in many directions (higher pensions and lower Government expenditure, full employment and stable prices . . .) without mentioning that these proposals conflict with each other. It is true that circumstances may suggest an order of priority; thus, if labour is in critically short supply, 4 (*e*) will rank above 4 (*g*); if the firm is faced with severe competition in price and quality, 1 and 2 will submerge 3 for a time, and 4 (*b*), (*d*), and (*f*) will rank above (*c*), (*e*), and (*g*), and perhaps above (*a*). But in all circumstances *orders of priority must be determined.*

It is no answer to say (as many managers would) that the single objective of making as much profit as possible can be used. We fully recognize the importance of profit-making, but the trouble is that the 'maximization of profit' is an idea with many alternative meanings, and it is again necessary to choose which should have priority in given circumstances.[1] For instance, a programme of research may reduce profits now, but give promise of increasing them in the future. Is it the long-run or the short-run profits which are to be maximized? The answer clearly depends on the financial strength of the firm and on its prospects of raising money from outside. Furthermore, when managers talk about making as much profit as possible, they do not really mean making every penny which can be extracted by a ruthless exploitation of every bit of monopoly power which the firm possesses. They mean making profit *subject* to reasonable treatment of employees, to giving customers a good service and retaining their goodwill, to keeping equipment in good order and up to date, to avoiding frequent and confusing price changes—in fact, subject to a whole list of conditions, which gets us back to the problem of priorities.

The objectives which a firm may reasonably set out to reach thus vary from time to time with the pressures of competition

[1] See *Investment in Innovation*, Chapter 4.

and the opportunities of innovation.[1] The problem is so complicated that, in order to get a clear guide to action, many firms have recourse to a 'rule-of-thumb' method, such as the maintenance of a given profit rate, or a given share of the market, or the achievement of a desired rate of growth in output or in assets. Such rules may do well enough, provided they are revised as the obstacles and opportunities facing the firm change, but they are not a substitute for clear thinking about the firm's objectives.

If the objectives are uncertain, the ways in which research and development can contribute will be uncertain also. But even if the production objectives of the firm are clearly defined, or summarized in clear rules for action, it takes some effort to decide what research and development can do. Their possible contributions are many, as can be seen from the check-list in Chapter 1.[2] What they can do in a particular case depends on the answers to questions like these:

1. Is there a sufficient basis of fundamental knowledge on which applied science and technology can build?
2. Does the firm command the services of research or development workers of sufficient originality and skill?
3. What scale of effort can be made? In particular, has the firm got the financial and managerial resources to carry a project through the development period, which is often costly?
4. How long can the firm wait for results?
5. How receptive will the production departments be to new ideas, and can any consequent changes in management structure be made without too much stress?

[1] This is implicitly recognized in the statement of financial policy by Dr. Jaques' firm. It is stated (op. cit., p. 322) that:

'The efficiency of units of the Company shall be judged by the following criteria:

'(i) The profit made,
'(ii) The output per man-hour compared with that achieved by other units of the Company performing similar tasks,
'(iii) The output achieved compared with the theoretical potential,
'(iv) The labour turnover compared with that of other similar organisations.'

The main point is that operating efficiency may be high but, because of unusually severe competition for trade, prices and profits may be very low.

[2] P. 7.

The general rule is that decisions about research and development must be made, not only with regard to the productive purposes of the firm, but also with a clear-sighted appreciation of what resources the firm can command in technology, in management, and in finance. Research paid for but never used is a loss to the firm and to the country—though it must be admitted that sometimes work of low importance has to be done to keep together a research team during a lull in their activities. If research is treated in isolation from the production problems and from the financial and human resources of the firm, only loss is likely to result, because the research output will be mostly irrelevant.

It follows that research projects should be chosen either by a competent scientists who appreciate the production, selling, and financial problems of the firm, or (if such scientists do not exist) by a small committee which combines these various qualities. If a choice is made by single-minded scientists there is a danger of trying to develop a new product for which there is no market, or one requiring capital or technique beyond the capacity of the firm, or a new process which cannot be worked economically except at an output greater than the market can bear. A choice of research projects by a non-scientist may mean that difficult or impossible things are attempted, while simple and promising things are left unexploited because of ignorance.

If research and development are to play a significant part, those in charge of them must not be confined to a minor place in the management hierarchy. For research not only has a part in helping a company to achieve certain objectives, despite the pressure of competition; it also makes it possible to identify new objectives, an activity which should properly take place at the top of the management structure. The research director should not be regarded as a 'back-room boy', expected to keep quiet until he is asked a question or until he can get the firm out of a difficulty.

So much for general attitudes; but what are the procedures by which they are to be expressed in a research budget and a particular list of research projects? We have seen in Chapter 1 [1] that the actual scale of research effort varies greatly from industry to industry, and still more, of course, from firm to firm. We

[1] P. 6.

have mentioned some of the factors causing this variation, and their consequence is that a firm can get very little help, in deciding its own optimum expenditure, by looking at the general practice of its industry. What is it to do instead?

The appropriate procedure in firms which have already established research and development as a working management technique is fairly simple, even though it does not give a precise answer. It is to start by compiling a list of desirable research and development projects. This list, which would result from suggestions by and discussions between research, production, and sales departments, will be based on research and development economics; that is to say, the problems would be judged both to be capable of scientific solution and to be commercially significant.

A list of projects thus formed will not usually be at all homogeneous. It may contain any or all of the types of work described in Chapter 1 as basic research, background applied research, product and process-directed research, and development; and the balance between these different types of work will vary greatly from one firm to another. The list may contain projects capable of yielding saleable final products next month and projects which will not yield anything for ten years; it may contain some projects whose outcome is virtually certain and others subject to a great degree of uncertainty; some costing a trivial sum and others likely to strain the financial resources of the firm. The part of the research and development cost which is likely to fall in the next twelve months will also vary greatly. It is commonly true to say that as a project moves through the stages of research, and on to final development, it will become more certain and definite (because alternatives will have been eliminated) but also more costly; this is because the 'ironmongery' of prototypes and pilot plants is frequently expensive.

The problem is, therefore, to put this heterogeneous list in order of priority, and to relate it to other possible uses of the firm's resources. It is important that this should be recognized to be a difficult problem, and that a good deal of thought and care should be given to it. Theoretically one would like to pick from all the uses of funds, including research, those of highest priority, to a total equal to the funds likely to be available; and this process of selection would automatically yield the research

budget. In practice, of course, even the most efficient firm cannot attain such precision, and the fixing of a research budget often appears to be little more than guesswork. Nevertheless, we think it important that managers should do what they can to make estimates of the yield from the various uses of the firm's funds, including research and development. This will help to eliminate projects which have been started for the sake of prestige, or to maintain a 'research empire', or out of habit, or without a proper assessment of commercial possibilities; while the periodic examination of rejected research projects may reveal some which are plainly a better use of funds than (say) the maintenance of lavish stocks.

Very little can be done, however, to estimate the yield of *basic* or *background* research, at least until they start to produce an outflow of usable results. Basic research is an activity undertaken by some large firms, because they think it wise to strengthen the scientific foundations on which the technology of their industry rests. They also hope (no doubt) for a big 'break-through', an outstanding change in technology; and by undertaking basic research they become more likely to retain the services of first-rate and original scientists, who will incidentally help in solving problems arising in development, and whose presence will help to attract able young men from the universities. Background research is a little nearer the point of application, and is often concerned with the properties of the materials with which the firm works, or with the characteristics of the processes which it uses; but its outcome, like that of basic research, is essentially unpredictable, at least in the early stages.[1]

The place of basic or background research in the programme thus has to be decided by general considerations of balance. The firm must ask itself whether its resources allow an allocation to this type of general exploration, and whether it seems appropriate to try to strengthen the scientific basis of production in

[1] For a description of a judgement about 'long-range exploratory research' in a large firm see A. H. Wilson, 'The Organisation and Planning of Research and Development in Courtaulds Limited', in Edwards and Townsend, *Business Enterprise*, Macmillan, 1958, p. 317. The long-range exploratory research on new synthetic fibres started in 1945 led to the commercial production of Courtelle (the only acrylic fibre of British origin) in 1958.

this way. The evaluation of research directed to particular products or processes can usually, however, be more definite. Two stages of evaluation can be distinguished. The first is an exploratory stage, in which priorities must be roughly determined by considerations such as these:

1. Is the problem scientifically promising, given the resources of the research department?
2. Would the result of successful research be appropriate to the interests of the firm?
3. Are the commercial prospects reasonably promising?

But once research goes beyond the first stage of exploration, the questions begin to become more definite: inquiries can be made about the availability of raw materials, the price and quality of competing commodities, and the possible markets and end-uses for the product, and preliminary thought can be given to the likely manufacturing costs and management problems.

As long as the project remains at 'laboratory scale', however, the cost data will tend to be unreliable and incomplete. It is in the development or design stage that better costings can be produced, markets can be examined (and perhaps tested with the products of a pilot plant), and the problems of full-scale manufacture surveyed. For a new product such matters as the requirements for sales organization and technical service can be examined; for a new process, the running cost at various levels of output can be looked at in relation to the markets for the product, and the best methods of controlling the process considered. Patent problems will have to be looked into, and guesses made about the reactions of competitors over a period of years. From all this mass of information a judgement of priorities in development can be formed, even though it may be subject to constant review and amendment, until at last the final decision to accept or reject a particular innovation is made, as described in Chapter 7.

Thus far we have suggested how priority lists can be formed at different stages of research and development. Their relation to one another will usually be determined by a desire to have a number of projects 'in the pipe-line'; and thus the full programme for research and development will consist of some high-priority items from each of the stages of preliminary explora-

tion, later applied research, and development. At times the competitive or financial need of the firm may be such that special emphasis must be given to developments near to the point of application; at other times a look into the dangers of the future may suggest that more exploratory research should be started. The balance of the programme thus requires frequent review—probably more frequent than will be welcome to the scientists, who often like to see a project, once started, pushed through to its end, even though its commercial purpose may have disappeared.

The process of programme-building which we have described appears vague and uncertain, but it is important not to make it still more uncertain by refusing to give conscious thought to the problem of priorities. Experience may in fact give quite a good idea of the chances of success of research projects, and in particular it may yield an estimate of the 'wastage rate'. In laboratories we visited, between 50 and 90 per cent. of all projects are rejected after a little elementary research, and still more are rejected when further expenditure on development reveals technical difficulties or excessive cost, or when the initial assumptions (e.g., about markets) turn out to need change in the light of new information. (In some kinds of chemical and pharmaceutical research, the process of discovery is one of testing and elimination, and the testing of thousands of compounds may yield only one with useful properties.) The elimination of projects is in a sense 'waste', and the waste can certainly be reduced by careful evaluation of projects before they are started; but it cannot be avoided as long as research and development are themselves necessary—that is to say, as long as the answers are not known without experiment. It follows that the research budget should not assume that each project, once started, will be carried right through to final development; it should allow for the 'wastage rate' suggested by past experience.

The list of research and development projects will have certain implications for the finance, research, production, personnel management, and sales departments. These implications should be clearly stated. Thus, the direct cost of research and development should be allocated to different time-periods, with allowance for wastage; and a rough estimate should be made of

the consequential cost of new plant and equipment if development is successful and is followed by production. The requirements for research and development personnel in different periods should also be estimated. The first approximate answers should be given to questions about management and sales. How far could the research and development programme be managed by people already available? What would be the difficulty of managing the innovations expected to result? Would they (for instance) require new divisions of the company, would there be a danger of serious 'teething troubles', and would co-operation from other firms be needed? What sort of sales-promotion problems would appear?

When these implications have been considered, the list can be looked at again, pruned of some fanciful projects, and altered. It then becomes a check-list of possible projects, but if there has been a free flow of ideas the research and development costs involved may well be beyond the resources of the company, and the ultimate investment in plant and stocks may cost more than the company can hope to save or borrow. At this stage, therefore, it is necessary to look at the check-list of possible projects against certain other pieces of information: a first estimate of what the company can hope to spend on new projects of all kinds during the next few years, and the claims of such things as finance for stocks and work in progress, for extension of existing types of equipment, for new buildings, for sales organization, reserves, acquisition of outside interests, &c. It is at this stage that estimates of the yield of different types of expenditure are needed. Rough as they may be, they will help to eliminate wild guesses.[1]

Any money figure set to the research budget needs to be checked back against the 'real' factors. If the budget is increased, can the extra scientific personnel be found? It is difficult to increase research and development effort quickly without loss of efficiency. Can the firm absorb the likely output of developed projects? We have found companies which have needed to reduce a research programme which they could well afford, because it threatened to outrun their capacity for managing innovation.

[1] For a further discussion of the problem of choice, specially related to investment decisions, see Chapter 7.

Thus the essential points in deciding the size of a research programme are: that there should be a regular (say, annual) review of a list of research projects considered to be both scientifically and commercially feasible; and that the number of projects carried, though it may originally be a matter for arbitrary decision, should be checked and revised by giving some explicit attention to the resources available and to the yields obtainable from different uses of funds.

This procedure is difficult to apply to a firm which is starting research and development for the first time. It still needs a check-list of possible projects, but it will lack people with the experience to compile it. This is a point at which a good consultant will be of great value. In deciding how much money to set aside, it is sensible to look mainly at the 'real' factors. Research and development will fail to grow into proper relationship with the rest of the firm, and to acquire the right commercial objectives, if it is started on too large a scale or hurried in its growth. Initially the right kind of work may be the piecemeal improvement of existing products and processes, and the correction of faults appearing in production, rather than big new projects. Therefore the first research budget may well be confined to the cost of a first-rate man and his necessary assistants; the budget can be left to expand naturally as the department 'finds its feet' and becomes able to tackle longer-term projects without upsetting relationships with other parts of the firm.

CHAPTER 5

The Day-to-day Management of Research and Development

INDUSTRIAL research and development set some special and difficult problems of management. The research and development programme needs to be kept in close relation to the financial and selling position of the firm, and (as we have suggested) research should be regarded as one of a group of related management techniques. From this it might seem that 'a research department in a company should be on the same footing as other departments. A research laboratory should work just as efficiently, should produce reasonable results and should be required to follow directions and keep within the company policy just as much as the planning and construction, production and selling units'.[1]

Yet, in contrast, it is often said that research needs to be free of any external direction or organization,[2] and that it is this freedom which makes the universities pre-eminent in scientific work. It is suggested that the key to successful research is the unpredictable creativeness of individuals, and that 'in running a research establishment one is really running a gambling concern and taking uncalculable risks for unassessable rewards.' [3]

The conflict between these attitudes is, however, more apparent than real. A management system which allows freedom to creative individuals is just as possible as one which organizes everything in detail. The amount of discretion left to individual factory operatives must necessarily be small, since the co-ordination of their efforts in the productive process is so important;

[1] *The Organisation of Applied Research in Europe, The United States and Canada*, O.E.E.C., 1954, Vol. 1, p. 29.

[2] See, e.g., Mees and Leermakers, *The Organisation of Scientific Research*: New York, McGraw Hill (2nd edition), 1950.

[3] J. D. Bernal in *The Direction of Research Establishments*, H.M.S.O., 1957, Part A, p. 1.

qualified research workers, on the other hand, can often be allowed much more freedom to decide the nature, speed, and method of their work, and it is true that they may need this freedom if they are to produce worthwhile results. Each situation has its own management problems; the orderly management of freedom for research is just as much a problem as the organization of a complex production process. Failure to think about the management of research will produce, not creative freedom, but a self-destructive anaschy.

The different types and stages of research and development give rise to different problems of management, and need to be organized in different ways. Projects of basic or background research are defined by the area of knowledge to be explored, but just what will be found in the course of that exploration is unknown, and therefore there can seldom be any question of organizing to create a *particular* result. The object of organization is to make it as likely as possible that there will be *some* useful outcome—for instance, by bringing together people of different scientific training, who may 'cross-fertilize' each other, and by making it possible to concentrate effort quickly on a sector where a promise of worth-while results appears. Thus current knowledge of the influenza virus owes much to work on ferrets which began with a study of dog distemper; the addition of new skills as the work developed made it possible for the research to branch out into the important technique of ultra-violet microscopy. The study of virus diseases, in fact, offers an example of long-range exploration whose course could not have been predicted, and the right way of going about it is the 'initiation of the work by men who have a clear idea of what they want to do, and have at their disposal a technique by which at least a start can be made, followed by readiness at any time to enlarge the scope of their effort by bringing further people into the work in response to such demands for expansion in specific directions as may become apparent'. [1]

[1] Sir Charles Harrington, *Staff Groupings and the Flow of Authority*, in *The Direction of Research Establishments*, H.M.S.O., 1957. It is, of course, conceivable that an effort could be made at the beginning of an exploratory project to foresee all its possible developments, and to assemble a team capable of giving comprehensive cover. This is likely to be so costly, and to lead to such waste of time (and consequent frustration), that it would be attempted only in a very urgent case. Possibly the American work on atomic bombs might provide an example.

In contrast, certain types of development can be planned with considerable certainty. For instance, it is often true in the chemical industry that at the pilot-plant stage the main problems are already known, and the remaining work can be foreseen in fair detail. This makes it possible to organize a co-ordinated attack along several lines at once, assigning workers their specific tasks. A tighter organization is also needed at the development stage to prevent waste of time later. The technical solution coming forward from the scientists has to be related to the production and marketing problems of the firm. Unless the production and sales staff have a chance to express their views during development, they may bring forward important new points when investment for full-scale production is in progress. There is a temptation for production engineers, if they have not been consulted earlier, to try to improve on the fully developed design, and this is a frequent cause of delay in commercial operation. It is quite a complex matter to organize a multiple attack on the identified technological problems, while at the same time consulting several other departments, and in consequence the appropriate size of the team of scientists may be much larger at the development stage than in research.

The organization appropriate for research which is product- or process-directed might be expected to involve some intermediate balance between planning and freedom, but in fact the wise course is to think out each case from first principles, for there is much variety in the types of research work undertaken by firms. It would certainly be misleading to lay down rules for *the* best organization of research and development. We can, however, suggest some more basic principles; and this we do first for departments which are concerned with research alone (and not with development).

The basic differences between the problems of organizing research and of organizing production have already been mentioned: it is more difficult to define the research outputs in advance and to produce them to order, and research workers need a much greater degree of personal discretion. It follows that it is misleading to think of research organization in terms of a hierarchical authority structure, with one class of people making decisions and issuing orders and another, much larger, class

carrying out orders. The main problems of managing research are:

(1) the choice of projects (a matter discussed in Chapter 4);
(2) the avoidance of undue gaps or overlapping in the research programme as a whole;
(3) the allocation of projects to individuals or groups;
(4) the recruitment of staff appropriate to the research programme;
(5) the provision of the necessary technical services.

This means that a lot of thought has to be given to *starting* projects and to *servicing* them, but not to giving orders about the future course of each project, for this course cannot usually be foreseen. The efficient work-group is necessarily small, and in it, in accordance with the traditions of science, emphasis is given to the authority of fact, not the authority of social power, and to independence of thought rather than the performance of tasks to order. The management of research workers in such circumstances is general, rather than detailed, and occasional rather than continuous.

In a small laboratory employing five or six qualified scientists there may be no need for the head of the research department to create a formal organization. The preparation and conduct of the research programme can be discussed informally by the whole group of scientists. As the department grows, however, some formal organization will be found to be necessary. Much industrial research requires team work, and however strong the feeling that all scientists are equal, someone has to organize the necessary co-operation. The head of a small department can perform this function informally, but in a department with several research teams he cannot act as informal leader for all at the same time. Furthermore, a larger department will probably call on more varied skills, and the head of the department is likely to be a specialist in some particular field of science, without much competence to lead a group working outside his specialist field.

The formal organization which grows up naturally in such circumstances involves the appointment of section leaders, each with the appropriate competence to act as organizer of the required co-operation within one or more teams. The sections

may be defined as covering particular fields of science, or particular stages of application, or particular areas of investigation; but however they are defined, there will tend to be a frequent need for consultation between individuals in different sections. The danger of even the simplest formal organization into sections is that this consultation will be impeded; people will start thinking in terms of a hierarchy, in which A takes 'orders' only from B, and may not help C (in another section) without authorization from the top level. It is necessary to emphasize that, though section leaders exist to make team work easier, they must not prevent the growth of a complex network of communication between individuals in different teams.

In organizing research it should be remembered that the individual scientists are generally the 'scarce resources' round whom, and in the light of whose needs, the organization should be built. Hence the common insistence that 'men are more valuable than equipment'. Yet when the equipment required for research becomes very expensive (as, for instance, in certain branches of atomic physics) the priorities may change. In order to get satisfactory use of the expensive equipment, it may be wise to have rather more programming of research work than the scientists like—more than they would require if the equipment were cheap and easily duplicated. In other words, the advisable degree of organization varies with the relative cost and availability of scarce scientists and of scarce equipment.

The type of organization which we have described gives the head of a large research department some difficult problems. Without having a close and authoritative control over his staff, he must nevertheless have a very good knowledge of what is going on. He needs this for several reasons. He must be able to advise his Board of Directors about the developments of product or process which may arise from research. He must be able to justify his claims for the research budget, and, when it has been fixed, he must allocate sums of money for different purposes. He must be in a position to support claims for the recruitment of scientists or the purchase of equipment. He must be able to make wise judgements about pruning or cutting off weak branches of the department's work, and encouraging others.

The abandonment of projects is a particularly difficult matter, and authoritarian action is liable to cause frustration and a

loss of the creative spirit. As far as possible, the workers concerned should be made to feel that the decision to abandon a project is their own, taken after full consultation and a proper examination of the facts, and is not being forced on them by people higher up. But this is possible only if the research workers can be persuaded to look at the full range of facts, commercial as well as technical, which are relevant to the decision; that is to say, research staff must be persuaded to think in terms of 'research economics', as defined on p. 40. It will be easier to achieve this if each research team is required to submit regular written reports, covering not only the results achieved (in relation to the objectives of the work) and the likely period for completion, but also the potential application of the results to the business of the firm.

The projects abandoned can be of three kinds. There are those which turn out to be scientifically insoluble or unpromising; there should be little difficulty in persuading the scientific staff to propose the abandonment of these. Then there are projects which are scientifically interesting and promise to yield results, but unhappily results with no substantial industrial use. Here the danger of frustration is considerable, and the importance of persuading research staff to think in terms of the economic importance of their work is obvious. Thirdly, and most difficult of all to abandon, there are projects which *do* promise worthwhile results, but results not so good as those which appear likely to be obtainable by an alternative use of research staff and funds. These candidates for the pruning-knife, the good projects of low priority, should of course be cut out only if there is no chance of making a case for a higher research allocation. Every effort should be made to get agreement that the chosen alternative project is more interesting or more urgent.

Thus far we have been talking about departments specializing in research alone, but these are in fact rare in British industry; they are typically to be found in very large firms in the chemical and electrical industries. It is more usual to find departments which are concerned with both research and development, and whose main emphasis is on development. In a development department, as we have already mentioned, the appropriate form of organization is rather different. The needs and problems have become more specific, and thus the programme can be planned

in more detail; also it is necessary in an effective development department to have a system of management which will ensure effective co-operation, both within the department and with the production and sales departments. It follows that a more direct system of control is required than in a pure research department—and this means a tighter time-table, and less reliance on the advice of the development staff in deciding what problems are to be tackled. But it is still true that the management cannot be authoritarian if it is to be efficient; for even though development can be planned in more detail than research, it still cannot be planned with any sort of certainty in any great detail. Unexpected problems arise that require quick consultation between individuals within and outside the development department.

We do not think it advisable to create a single pattern of management in a department which conducts both research and development. Otherwise, where the predominant activity is development, research will tend to be over-organized, and where research is the main activity [1] development will tend to be under-organized. The need for a hybrid form of organization is also obvious when a research laboratory has responsibility for routine testing and control for the production departments.

Sometimes a research and development department takes a new product or process, for which the company has no manufacturing experience or equipment, right on to full-scale commercial operation. The appropriate organization then has to be created *ad hoc*, and it is usual for some of the research staff involved to be transferred to manage the new operations. This happened in the Metropolitan Vickers Electrical Co., in relation to Burch's work (see p. 24): the responsibility for the design and construction of X-ray equipment was carried by the research department, and later a separate X-ray department was established, the senior staff of which was largely made up of past members of the research department (which now performs only an advisory function in what has become an orthodox field). The development of the electron microscope followed a similar pattern.

In a few companies which make a habit of producing varied

[1] Research is sometimes the main activity in these 'mixed' departments, if a large part of the firm's development work is carried by operating departments.

or unusual innovations this movement of people is formalized, so that it becomes a normal procedure for research and development staff to stay with their project until it is fully established in production. Such a free movement of staff is appropriate where the new product or process uses unusual techniques, which may give difficult teething troubles in conditions of commercial production; but it will work properly only if the organization of production is on a small enough scale to make possible the creation of a temporary informal joint organization of research and production staff, or if it is known that an entirely new department must in any case be created. An attempt to provide organized mobility of research staff into existing production departments of a large organization may run into grave difficulty.

This mobility of research staff is one way of easing the transition from development to production; and it is important to recognize that this is a stage at which difficulty may occur. It may be caused, for instance, by the need to call on the facilities or plant of a production department for development work, because there are not enough facilities under the direct control of the development group. This may be due to unreasonable delay in providing equipment, but it may also follow from a decision to avoid an uneconomic duplication of costly plant. For example, in the electronics industry expensive equipment may be needed by design and development groups for occasional use only, while in the paper industry a pilot plant would often be almost the same as the (very expensive) plant for full production, and the only possible policy is to try out improvements on the production department's equipment. This means that an important part of the development work may have to be done at week-ends or at some other slack time, which tends to slow up progress. A big development department, or one concerned with many opportunities of technical change, has a better chance of offering an economic justification for owning its own plant for testing out ideas. Thus the Russian Iron and Steel Research Institute has complete modern equipment for steel-making and fabrication, on which the research and development staff can try out a new idea from its first creation right through to the scale of commercial use. But the Institute is five times the size of the British Iron and Steel Research

Association; in this trade only a very large organization could afford such facilities.[1]

The use of production facilities for development is not usually an ideal solution, since the production department will not be keen to make room for 'outside' work unless there is excess capacity. Thus it is a good general rule that, where possible, development departments should have their own pilot-plant facilities; and where use of production equipment is unavoidable, the consequent problem of management and co-ordination should be clearly formulated and faced.

Where common facilities are used, the policies for development and production must clearly be co-ordinated; but this is a principle with wider application. It is foolish to carry through any development projects without considering the nature and timing of their impact on production and sales.[2] The relation of the various departments is one of potential conflict. It often happens that sales managers are crying out for greater variety, more attention to individual customer-needs, at lower prices, and works managers are, very reasonably, replying that greater variety means higher and not lower costs. The head of the research department may see a way of providing more variety or higher quality at lower cost, but only at the price of making the works manager's life a burden through a period of re-equipment and reorganization. Out of such a situation of conflict, mutual understanding must be created.

There is thus a good case for creating a powerful 'development committee', composed of the directors or managers of the development, production, finance, and sales departments, to keep under review the main lines of development policy and practice. Such a committee is especially valuable in a company where a danger of conflict between development and production staff is apparent. The need for this committee provides an example of one of the many ways in which the management of innovation cuts across a structure of line management: a tight and tidy organization of the firm according to lines of command is often quite inappropriate.

But of course a committee system has its limits. It may not solve some of the worst difficulties, which arise where it is actu-

[1] *Financial Times*, 6 February, 1959, p. 13.

[2] See also p. 39 above.

ally difficult to distinguish between design or development and production. In the engineering industry, producing a prototype machine and producing a machine for sale to customers may involve much the same processes and skills, but the attitudes of development and production staff may be quite different, so that their close association produces friction. The development staff frequently want to change things, to try one more experiment; the production department wants finality (even if it is imperfect) so that it can get on with the job. Design is not an exact science, and engineering designers may differ as bitterly as the proponents of different schools of architecture. Working drawings may turn out to be an imperfect method of communication; designers can be heard to complain that their whole work has been ruined by someone who has arbitrarily shaved off an awkward quarter of an inch of metal to make the machine easier to produce.

These troubles arise in part from the acute shortage of development engineers, which may be eased in time by the improvements in higher technological education. But they are natural enough in industries such as electronics and aircraft production, where practice runs ahead of theory, and design is a matter of art as well as of science. Clearly such industries need a flexible form of organization, which in suitable cases can allow a design engineer to 'nurse' a project involving novel production problems until regular commercial production is achieved.[1]

By contrast with the cases where the links between research, development, production, and sales are very close, there are cases where problems can be broken down in such a way that the division of labour can be fairly clear cut. For instance, some industries (such as the motor-car industry) are mainly assemblers of components. It is not very difficult to develop a new model away from the assembly line once the main principles of design have been agreed with the production engineers and the components, appropriately modified, have been collected together. *Basic* research may be quite satisfactory in isolation, and may indeed benefit from the simpler organization of an isolated unit, provided that communication problems (see p. 27) can be overcome.

Firms may find it helpful to look at the problem of organizing

[1] See p. 53.

research and development from another side. Instead of considering the organization simply in relationship to its functions, we will now consider how, in the performance of those functions, friction and trouble may be kept at a minimum. Research and development are concerned with change: the management of innovation is the management of change; and where there is change, the distinction between 'my job' and 'your job' becomes blurred and difficult to make, and there is opportunity for friction between individuals and for failures of co-ordination. It is true that the sense of moving forward, of being part of an advancing army, helps to make the frictions seem less important; frustration and friction are at their most acute in a static concern where business abilities are running to waste. But even in a highly progressive firm it is worth some trouble to make sure that clashes of responsibility are avoided, and that a state where 'everyone's responsibility is no one's responsibility' is not reached.

The existence of tensions between research and production staff has often been recognized, but it is worth while to observe that some of the tensions are transitory, and need not be taken as seriously as those which are permanent. Thus when a firm first recruits scientists, with the intention of putting traditional techniques on a scientific basis, there is liable to be mistrust between the scientists and those who have been running production. But this can in time be broken down—either by recruiting a new kind of production manager, with a greater degree of technological competence, or by a convincing demonstration of the usefulness of scientists. In old-established industries it is often wise to let research and development activity grow naturally out of technical service and 'trouble-shooting', which are clearly and immediately of benefit to the production and sales side of the business.

Another transitory cause of friction is that the salaries of research and development staff may be much greater than those of existing managers, and those who have 'come up the hard way' may be resentful of this and seek to frustrate the new-comers. Fear of this type of friction sometimes leads to an attempt by top management to isolate the research and development department, physically (for instance by housing them in a remote country house) or in terms of organization. Sometimes, as we

have seen, this may be the right solution; for instance, if 'research' means fundamental work on the properties of materials, isolation from production may not be of great significance; or if the research staff are working on a new product, likely to require entirely new production facilities, it will not matter much if they have little contact with existing production. But usually it is important that research and production staff should work closely together—indeed, such a close relation may be a means of lessening the frictions mentioned in the last paragraph. It may therefore be better to give existing managers higher pay, even if their formal qualifications do not suggest that they 'deserve' it, in order to preserve some kind of parity of status. The next generation of managers may well need scientific or technological qualifications, and expect a correspondingly high salary, so the anomaly will correct itself. In any case, some firms are apt to exploit those who have given long service and are too old to move elsewhere; the entry of the new research staff may be only the occasion for an adjustment which ought to be made anyway.

The tension arising from a shortage of development facilities is usually avoidable. Inadequate arrangements for making pilot plants or 'mock-ups' are a source of inefficiency in many firms, and a cause of friction between development and production departments. The trouble may arise because a research and development department has outgrown its original position as a testing or control laboratory responsible to the Works Manager. In its new functions it may appear to the production departments as a servant who is making inconvenient and troublesome demands on his former masters. The necessary first step to a solution is to alter the management structure so as to recognize that research and development need a direct and effective line of communication to the Board of Directors; then it becomes possible for the demands for development work involving a use of production time to be a subject of negotiation between equals, and not a plea for charity.

Tension of another kind may exist because management has failed to understand the natural differences in method and attitude between research and production staff. It seems to us that some psychologists and sociologists have overstressed the importance of continuing tensions arising from differences

of working methods and attitudes. The tensions may be transitory or easily removable, and appear permanent only because their cause has never been understood. Thus an attempt to impose a strict and authoritarian line system of management on the natural anarchy of creative activity produces strain; but one strain will only be replaced by another if the breakdown of the line system leaves people uncertain of where decisions have to be taken—of where policy is determined, where its execution is controlled, and how far discretion to make changes on technical grounds is allowed. The discussion earlier in this book suggests the right way of solving this management problem. Efficient industrial research requires a particular method of choosing research projects, and projects, once chosen, require periodic review; but between the times fixed for review the teams of workers need as much freedom from external interference as possible. The management of research should be general and intermittent, not detailed and continuous; and the research workers themselves should be involved in choosing projects and in reviewing them. To achieve this direct participation (which is a valuable way of relieving strain) the process of management must be kept informal—a point in favour of small research units.

In a development department management needs to be more detailed and continuous. Here one of the most important ways of reducing strain is to bring into the open the differences of interest and view, as between the development department and the other groups concerned, before a project is actually started. This may be achieved in a joint committee, such as that proposed on p. 54. The use of such a committee accords with the principle that if you need people's co-operation, you should get them involved at an early stage; it helps also, of course, to eliminate the projects which stand no chance of calling forth that co-operation. As a project moves forward, constant consultation with the production and sales departments helps to ensure that dislocation in production is expected at a given date, prepared for, and thus minimized, and that the timing of development suits the sales plans of the firm.

Another way of lessening friction is to have people of similar background in research and production departments; and this implies a use of scientists and technologists in production, which

we think should be greatly extended in British industry. People with experience (beyond mere initial training) both in development and in production are especially valuable, because they can most readily guide a project over the transition to full commercial production—often a weak point in the process of applying a new idea. Thus Dr. Bienfait of the Philips Research Laboratories at Eindhoven reports that a magnetic ceramic product, invented in 1951, was being produced in hundreds of tons by 1953, largely because 'the leader of the development group concerned was an ex-research-laboratory man and allowed three weeks' use of his factory facilities for this work, although this arrangement upset other production schedules'.[1] While we would like to see mobility of scientists and technologists between departments further encouraged, it is worth remembering that some of it happens naturally, simply because in some branches of science creative work seems to be a matter for young men. Not much is known about the relation between age and scientific creativity, and it is a matter deserving study at the level of the 'ordinary' scientist, and not just at that of the outstanding genius. Shockley suggests that the published work of scientists reaches a marked peak in their later thirties, and falls off (almost linearly) thereafter.[2] This might, of course, be due to their diversion to administration; more plausibly, it might be due to their having exhausted a given field of research. Sir George Thomson writes: 'How often a man of considerable ability continues all his working life in the narrow vein in which some dead and gone professor started him, long after it has lost interest and all the paying ore has been extracted.' [3] A change of scene, such as the doctor suggested to the dormouse, might restore productivity in research, though at the cost of a period spent in mastering new techniques. Or scientists from a number of establishments might have a period of joint work tackling some large problem, then returning with new ideas, techniques, and enthusiasm to their own laboratories; this might be possible for staff in the Government or Research Association laboratories.

[1] *The Direction of Research Establishments*, H.M.S.O., 1957, Part D, p. 3.

[2] *Proceedings of the Institute of Radio Engineers*, Vol. 45, p. 279. See also H. C. Lehman, *Age and Achievement*, Princeton University Press, 1953.

[3] *The Strategy of Research* (Fawley Foundation Lecture), University of Southampton, 1957, p. 9.

But even if creative work can be prolonged by such devices, it is certain that by the age of forty many scientists will have moved (to oversee some project) into a production department, or will welcome the stimulus of a transfer from research to development, or from development to production, or to technical sales or general management. Since research is a swiftly growing activity in Britain, and in consequence many research scientists are young, it must be expected that transfers of this kind will become more frequent in future, with benefit to the relations between research and production departments.

How far is it possible to improve the effectiveness of research effort by attention to organization *within* a research department? The important point here is to give workers a sense of urgency and purpose, without which they may console themselves for an absence of striking results by giving an exaggerated importance to thoroughness and detailed knowledge.[1] This can be achieved in part by helping the research staff to understand the commercial importance of what they are doing. Sometimes (in a large concern) the incentive of tackling new problems can be provided by organizing the research department, not according to subjects, but on a 'project' system, under which all staff are available for membership of research teams chosen to solve a particular problem, and these teams break up when the problem is solved. A man is not therefore kept working in the same narrow groove, with the same colleagues, for year after year. Such a method of organization is difficult to use, especially if the objective of research is broad or uncertain; but it may at least suggest the possibility of loosening up the organization of a department which has become too rigidly divided by subjects.

The latter part of this chapter has been concerned with tensions and frictions, and it may leave the impression that a tendency to friction is inevitable. This is not, of course, true; a production department, for instance, sometimes contains an engineer or scientist who is the driving force behind change, and pulls the research and development staff along with him. Sometimes, but not very often; surveys of the origins of innovations commonly show that only a small proportion originate from production staff.

It is often difficult for those who are pre-occupied with press-

[1] See Sir G. Thomson, op. cit., p. 14.

ing day-to-day problems to spend time in understanding and solving the management problems which we have discussed in this chapter. For this reason alone it is often wise to call in management consultants, and they will be especially necessary if the firm has little experience of changing a management structure to meet a new situation. But even in firms which do not lack this experience, it is remarkable how often a change, which has been recommended in detail from within the firm, is adopted only when attention is focused on it by a report from outsiders. Consultants are often treated as doctors to be called in when the organization is sick; but it is worthwhile having a periodical review or 'check-up', comparing what actually happens with what should happen 'on paper', and both of these with the needs arising from the firm's current activities and with the practice of other companies. In a large firm this regular review may be the function of an Organization and Methods group, but even this may need an outside check to make sure that it has not become set in its ways.

In all such reviews it must be remembered that industries have different and changing problems: no rules for the day-to-day management of research and development will serve for long, except the rule that the problems must be recognized, examined, and faced—not once, but repeatedly, as conditions change. A rigid system of management is inappropriate to a changing situation; arrangements for changing management structure must exist and be used. One of the most important skills of top management is to facilitate changes in the management process at lower levels, and research (being a strange and variable activity) is especially likely to call for the exercise of this skill.

CHAPTER 6

Innovation and the Smaller Firm

To the owners and managers of a large proportion (by number) of the firms in British industry, all this talk about research and development will seem beside the point. Research is typically an activity of large firms. In the United States eighty of the biggest firms employed in 1953 half of all the scientists and engineers engaged in industrial research and development.[1] In Britain half of all research and development workers in industry in 1955 were employed in sixty-one establishments, and 80 per cent. in 309 establishments (each employing more than fifty research and development workers).[2] To get half of *all* employees in British manufacturing industry it is necessary to take over 3,000 of the largest establishments, and to get 80 per cent. some 15,000 establishments are required. The difference is partly accounted for by big firms concentrating their research in one of their many establishments, but it remains evident that the concentration of research in the big establishments is much greater than the concentration of production.

This is the position as it is, but what can we say about what ought to be? How large must a firm be before it contemplates doing research of its own, what work should it attempt first, and what lines of progress are open to a firm which decides not to attempt its own research? The question about minimum size can be given a rough answer with the help of a recent survey by D.S.I.R.[2] Expenditure per person employed on research and development, in manufacturing industries other than the aircraft industry, was in 1955 roughly £1,300. These industries employed 25,600 scientists and engineers (excluding Higher

[1] *Scientific Research and Development in American Industry, 1953*, U.S. Department of Labor, Bulletin 1148, p. 6.

[2] *Estimates of Resources devoted to Scientific and Engineering Research and Development in British Manufacturing Industry, 1955*, Department of Scientific and Industrial Research, H.M.S.O., 1958. Note that the British statistics are in terms of 'establishments'—i.e., roughly, factories—and one firm may have several establishments.

National Certificate holders) and 58,600 other research and development staff. It follows that the cost per scientist or engineer was over £4,000. But average research and development expenditure per person employed was £17, so that an 'establishment' containing even a minimum research unit with a single scientist would have, on the average, 250 employees. The average in the chemical trades would be sixty employees,[1] in metal manufacture over 450, in textiles about 600. A research unit of the minimum useful size might well need several qualified scientists and engineers. It appears to follow that, according to the 1955 pattern, research is an activity seldom to be contemplated until the number of production employees runs into hundreds, or even (in some trades) into thousands.

It does not follow, of course, that the 1955 pattern is right, though the shortage of qualified scientists and engineers means that it is hardly likely to be changed quickly. Nor is it wise to put too much reliance on averages, for there are great divergences between individual firms. We have noted some quite small firms which do undertake research and development, at a cost of devoting to this use much more than a normal proportion of their total resources. Innovations do not all come from the big establishments; since the War important new developments in such fields as electronic components, instruments, adhesives, plastics, packaging, and metal processing have come from small firms. Indeed, some small firms have been created to apply new scientific ideas or skills to industry; unfortunately a number of these have failed because of a poor understanding of research as a management technique.

We must therefore say something about the management of research and development in those small firms which feel able to undertake these activities. They have to face some special problems. The first, as we have already implied, is that the minimum size of a research unit may be large relative to the total employment of the firm. The second is a result of the unpredictability of research and development work. In a large research organization, where many lines of inquiry are pursued at the same time, successes have some chance of being in a statistical balance with failures; but a research unit of minimum

[1] It should be noted, however, that this is a deduction from data obtained from establishments with 100 or more employees.

size may by chance go on for a considerable time without getting any 'return' from successful products or process. Such a period of failure causes financial difficulties, which a small firm is particularly unlikely to be able to bear.

The fate of the hen trying to hatch a single infertile egg can perhaps be avoided if the hen tries to hatch a dozen eggs at once; but such a policy of diversification puts a lot of strain on the management and on the finances of a small firm. We have noted a number of highly specialized firms which were able to support development work as long as it was done on defence contracts, without much risk, but which ran into difficulties when defence policy changed. The aim of the small firm, in fact, must be to minimize 'research risk' by some means other than a costly diversification. It needs to keep the gestation period for innovations short, and to plan research and development policy so as to yield the ordinary good-selling line, rather than the exceptional product, full of promise but also full of risk.

This implies that the emphasis should be placed on *development* rather than research, and on those types of development which do not involve heavy capital expenditure and a long wait. For work of this kind (if it can be found) a small firm may actually have some advantages. As Clifford Rassweiler picturesquely describes it, in large firms 'rolling research dollars down the long treacherous track from the research flash of genius to the point where aggressive production and sales departments can make these dollars multiply into profits, is frequently a tormenting and frustrating activity'.[1] But a small firm can readily develop close and direct working relations between development, production, and sales staff; it may be possible to follow the plan (mentioned on p. 53) of letting one scientist or engineer see a project through from the first steps of development to full commercial production.

This flexibility and ease of communication in small firms shows up to most advantage in cases (of the type mentioned on p. 55) in which there is a possibility of conflict between design and production engineers. The design or development engineer works out the details of a product which satisfies certain needs and conditions; the production engineer grumbles that this is

[1] 'Converting Research Dollars into Profit Dollars', *Chemistry and Industry*, 8 June 1957, p. 717.

'college-boy stuff', difficult to build and needlessly complicated for the stern realities of production or maintenance. Yet if the production engineer re-designs the product he may reduce its performance in some important way. The conflict is similar to that which sometimes occurs between architects and builders, and which the building industry is learning to avoid by bringing the 'producer' (the building contractor) into consultation at an early stage of the planning. In industry the conflict may be traceable to the designer's ignorance of production problems, or to his failure to make clear exactly what operating conditions are envisaged for his design; or to the production engineer's failure to understand design problems and to refer back to the original designer when a change is proposed. These problems of communication and understanding are much easier to solve in a small industrial community, and we think that this is one reason why small firms have made significant innovations in electronics, instruments, and control systems.

A small firm can, however, develop its special capacities only if it has a clear understanding of its special limitations. The general rules proposed in Chapter 4 (pp. 38–9) for the choice of products for development and for commercial production apply here with particular rigour. A development project should be accepted only if there is reason to believe that its technical problems will be solved fairly quickly, that the subsequent investment in plant, stocks and work in progress will be within the capacity of the firm, and that the production and marketing problems will not cause overstrain. All this calls for a realistic analysis of what the firm can hope to achieve; there will be no attempt to compete in fields where large-scale development work, financing, and marketing are required, nor to rely on innovations which are scientifically exciting but commercially precarious. In other words, however 'research-minded' the firm, success depends on a fair balance between innovations and 'bread-and-butter' work, and on a correct analysis of commercial possibilities; the demand for scientists should be based on this analysis.

Small firms which undertake development work are liable to over-expansion; like plants treated with a hormone weed-killer, they may grow too fast and out of proportion, outrun their strength, and die. It is hard to refuse the opportunity for quick

expansion offered by a successful development, but it is wise to be cautious, remembering that growth creates managerial problems and that production skills and 'knowhow' cannot be bought or created quickly. We have noted this quality of caution in successful small-firm innovators, and we have also observed that (knowing their limitations) they are ready to seek outside help in solving the technical problems of expansion.

Thus far, having pointed out that most research and development work is carried out in large firms, we have been discussing the special problems of those small firms which nevertheless decide to undertake their own development. Such firms are important to industrial progress, but they are few. What of the great majority? Some, of course, are backward, but unwillingness to tackle development work may be a sign of realism, not of backwardness. A great many firms are obviously too small to carry even the minimum amount of development; others are wise in refusing to complicate their problems by undertaking a difficult and chancy new activity. Few farmers undertake agricultural research, but this is not in itself a criticism of the efficiency of agriculture or of the size of its units.

Two things are important to the technical progress of small firms which do not undertake their own development: a readiness to look out for and receive ideas developed elsewhere, and a readiness to make intelligent use of outside help. Both of these are more likely to exist if the firm employs scientists and technologists. This is a point which we have made elsewhere;[1] here we wish only to stress that a firm which does not employ scientists in research has all the more need to employ them in management. Once again the successful small firm is one which is conscious of its limitations and which lays deliberate plans to overcome them. Thus a large firm may employ many different scientific specialists, each sensitive to development over the area of his own subject. A small firm may do no more than employ a single scientist, but the scientific area which needs to be surveyed will not be proportionately less. A systematic procedure for surveying the literature about new developments (such as is proposed in Chapter 3) is therefore more important; we would recommend small firms to consider appointing one of their staff as 'information officer', with special responsibility for examining

[1] P. 25: see *Industry and Technical Progress*, pp. 35, 129–35.

incoming literature and bringing it to the attention of others in the management. But ideas are not always put on paper, and the chances of getting them at trade exhibitions, on visits to other companies, or through contacts with sales representatives or customers must be kept in mind. Some companies have increased their sensitivity to this kind of informal communication by appointing a chief engineer with only a minor responsibility for day-to-day engineering matters, but with a major responsibility for discovering techniques likely to be useful in the firm. This procedure can bring, in a quiet way, significant results. For instance, by sending such an engineer on the productivity team 'circuits' arranged by a local Productivity Committee, some firms have been able to pick up useful new techniques from other industries.

Although a firm which does not undertake its own development can pick up ideas from outside, these ideas will sometimes need adapting, improving, or extending to fit the firm's needs. They may also react on other parts of the firm's work—requiring, for instance, materials with different qualities or machines of greater accuracy. The extra development or adaptation is often done by the supplier of the idea—e.g., the supplier of a new machine—but, if this is not possible, the 'intelligent use of outside help' becomes important. There are various ways in which development time can be bought—from consultants, sponsored research institutes, or research associations. These should be used more than they are; a small firm's need for research and development is intermittent, and it should think in terms of chartering research or development facilities, just as an oil company charters extra tankers when demand is above normal.

Some technical consultants have substantial research and development laboratories. Their services are used more by large firms than small, but there is no logic in this. Often a consultant —whether professional or 'occasional' (from a University or College of Technology)—can provide the expert knowledge required for a design problem or for the diagnosis of a fault which has developed in a process. For example, the director of one small firm, having read in the technical Press about some industrial possibilities of radioactive isotopes, sought the help of the Institute of Physics in finding a consultant to develop a new

method of measurement. With the help of this consultant the firm made a striking advance in machine design.[1] We discuss the question of sponsored work within research associations in Chapter 10 (p. 117). Its development is patchy, but it is, of course, supplemented by the commercial bodies which sell research or development facilities. It is difficult to say whether the facilities are adequate; they appear thin, in comparison with those available in America, but the trouble may be an insufficient urgency of demand.[2]

The recommendations which we have been making in this chapter may seem painfully obvious; but the following figures, extracted from a recent survey of 'Technical Information and the Smaller Firm', published by the European Productivity Agency,[3] suggest that there is ground to be made up. The figures for the different countries are not closely comparable, but the broad impression which they give is probably correct. It is an impression of the lack of formal organization for achieving technical progress in many British small firms.

	U.K. (*b*) (%)	Germany (*b*) (%)	U.S.A. (*b*) (%)
Proportion of small firms having on their staff a 'technical adviser' with a University degree	17	22	52
Proportion of small firms showing a high 'level of organization' for technical information (*a*)	24	23	36
Proportion showing a low 'level of organization'	45	35	34
Ditto (metal and engineering only)	56	35	20
Proportion using consultants when unable to solve problems themselves (*c*)	19	24	34
Ditto (metal and engineering only)	18	27	34

(*a*) 'Level of organization' is based on a composite mark involving the use of technical advisers, the buying and circulation of journals, the use of abstracts, and the buying of books.

(*b*) United Kingdom—firms in metal and engineering trades, electrical manufacture, and food manufacture, average number of employees about 240; United States—same industries plus textiles, average number of employees about 190; Germany—mostly metal and engineering, but some textile firms, average number of employees about 285. The German sampling methods were poor.

(*c*) In interpreting these figures it must be remembered that there are more research facilities supported from public funds in Britain than in the other countries (though it is not certain if this is true of *development* facilities); and that the German firms chosen received a lot of help from industrial research associations established by their trade.

[1] *Industry and Technical Progress*, p. 36.

[2] See p. 118.

[3] Paris: O.E.E.C. (London; H.M.S.O.), 1958.

Though in this chapter we suggest various things which small firms can do for themselves, it is only fair to say that, as one goes down the scale of company size, the influence of the environment becomes more important. A big firm can change or ignore its environment; a small firm depends much more on the existence of facilities provided by others. For instance, small firms will be better able to progress if research associations are willing to do development work, and to 'sell' developments through an effective liaison and consultancy service;[1] or if larger firms providing materials or machines are good at development and at technical salesmanship; or if trade or local associations help to develop training facilities, to encourage the exchange of information, and to improve and publicize consultant services. If we were asked to pick out one feature of the environment of a small firm as of special importance, we would choose good technical salesmanship; for if a small firm's suppliers offer not only goods but also ideas, advice, and help with 'teething troubles', they are indeed giving the firm a chance to help itself.

[1] See p. 116.

CHAPTER 7

Some Money Matters

THE questions which come forward in this chapter are concerned, not with the finding and direction of physical resources to speed technical progress, but with the associated money matters—with finding the money, with the financial control of investment policy, and with price policy. While it would clearly be wrong for us to pretend to generalize about the varied financial problems of firms, we think that there are some things to be said about the right questions to ask and the right tools to use in making decisions.

We have, in visiting firms, noticed that in dealing with financial matters they are beset by two opposite dangers. One is the danger of making decisions without looking at information which can (without much trouble) be obtained. In particular, there is a good deal of neglect (and a suspicion, not sufficiently justified) of cost accountancy. Owing to this self-imposed ignorance, firms have been found to carry on for years production departments whose returns did not even cover their labour costs. The other danger is to be bewitched by the apparent precision of accounting figures, and to forget the assumptions on which they are based. It often happens that the same situation can be described in different accounting forms which leave different impressions on management; and unless managers are aware of this, they are placing a lot of power in the hands of the accountant. He is a valuable servant to management, but the master should understand what the servant's labours are about.

There is a general economic maxim, 'If prices diverge greatly from costs, look out for trouble.' Thus, it seems to be well established that the cost of providing long-distance passenger transport on a well-used route by fast express trains is low, while the cost of short-distance stopping trains is high—especially on routes where traffic is mainly concentrated at short peak periods.

But rail passenger transport in Britain is mostly charged at a uniform rate per mile; consequently, faced by various kinds of competition from road transport, the railways lose traffic on long-distance routes, on which they have low costs, and retain traffic on short-distance routes, which may be difficult to operate except at a loss. Some commentators would ascribe a considerable part of the troubles of the railways not to their technical obsolescence, but to the fact that conservatism and Government regulation have combined to create an irrational pricing policy.

If a firm is operating in a market in which the prices are effectively set by others, it has no 'price policy'; the effect of failing to know costs or of ignoring what is known will then be that the firm has no basis for knowing which of its activities should be expanded, which rejuvenated, and which closed down. It may be misled by the overall profitability of its enterprise into continuing the output of a product, or the use of a process, which in fact need radical alteration. An overall loss may mean that it is blind to the value of an innovation which it has started.

Similarly those firms which (because they have not got numerous direct rivals selling just the same product) have some power, within a certain range, to set their own prices, will if they ignore or fail to know their costs have no better criterion than their overall profitability to decide the value of particular lines of production. Their prices may in some lines be too high—perhaps limiting sales so that the full possibilities of an innovation are not realized—and in some lines too low, encouraging sales at a loss while failing to reveal an inefficient method which is causing the loss. False pricing may also affect the policy of other industries; thus if a commodity is kept artificially cheap, innovations designed to economize in its use (which from the point of view of true social costs may be desirable) will tend not to happen. Many economists have argued that the price policy for coal has been faulty in this way.

The failure to know costs is most likely when the firm produces 'joint products'—that is, when it is difficult to sort out the costs of different lines of production; there is a large element of 'joint costs' which have to be allocated according to some rule. About this situation there are three things to be said. First, it is common for firms to exaggerate the extent of joint costs, because

the detailed analysis of costs is a troublesome and specialized business. It may well be that a fresh look at the problem would show the necessary extent of arbitrary allocation to be much less than was originally thought. Second, it may be that management methods can be changed so as to throw up data about costs of particular lines of production more efficiently. Third, where arbitrary allocation takes place it is important not to forget that it is arbitrary; if a decision has to be made, using the costing so obtained, it is worth while experimenting with alternative plausible allocations of joint costs to see if they would affect the direction of the decision.

An allied question of pricing policy is the cost of variety. Many British firms, in their anxiety to please their customers, are willing to provide variations of a standard product. Some of these variations are meaningless; they have no functional purpose, and have grown up largely by accident. Once established, however, a variation tends to be continued in repeat orders, and to be difficult to eliminate. The cost to the community of excessive variation is considerable, as is shown by the savings and productivity changes achieved by some firms which have been strong-minded enough to eliminate it. Thus a small company manufacturing waterproof cloth doubled its output without any significant increase in its stock of yarn, by reducing from thirty-one to twenty the number of qualities being woven;[1] a stationery works increased productivity by 30 per cent. by simple standardization, dovetailed into a programme of method improvement; [2] by using a limited number of standardized and interchangeable parts, a manufacturer of electric control gear was able to provide for various customer needs with higher productivity and a saving of material; [2] by reducing a range of types from thirty-three to one a manufacturer of gas cookers was able to cut price by around 32 per cent.; overall production rose by 165 per cent., while the number of employees rose by less than 32 per cent.[3]

The effect of excessive variation is to increase costs, and also to affect the efficiency of distributors and users, who have to

[1] *Management Techniques in the Smaller Enterprise*, British Institute of Management, 1954, p. 10.

[2] *Better Ways*, British Productivity Council, undated (1955?), p. 39.

[3] *Simplification in British Industry*, Anglo-American Council on Productivity (now British Productivity Council), 1950.

keep larger stocks and who lose the advantages of standardization. Much the most effective way of reducing variation is to charge a high price for it; that is to say, to offer the customer a choice between a standardized product (or a product built of standard components), cheap because it is costed on the basis of long runs, and an expensive custom-built product to meet the purchaser's exact specification. It seems to us that the choice is far too seldom given in these terms. Changes of method and improvements of products which can be justified on the basis of long runs may thus be inhibited.

In turning to investment policy, we must first examine the possibility that technical progress will be held up by lack of funds. In a later chapter (p. 148) we mention some of the things which might make the raising of capital, by firms which most need it, easier. At this point we must refer to the fact that many firms which claim to be short of money have never taken the trouble to find out about the sources from which they might get it. This is probably because they are suspicious of those who offer to lend money, and they believe that those who provide the finance will want to have more control than they are prepared to concede. In particular, family firms are often suspicious of anything which may dilute family control.

It would be foolish to regard these questions of financial control as irrelevant. A firm may quite properly claim the right to continue at a certain size or form of organization, even if this means that it has to forego opportunities of technical progress. But we think it important that the issues should be brought into the open. A firm should investigate the possibilities of raising money,[1] and find out what conditions would be attached, before claiming that it is impossible to obtain the necessary resources on satisfactory terms. It may also be relevant to inquire if the money is really needed. We find that small firms, in particular, often ascribe all their difficulties to shortage of capital, when in fact better management and organization would save money (e.g., by reducing stocks and overheads) and increase profit rates. A firm which has in this way shown signs of managerial competence is in a much stronger position to command the confidence of lenders, if later the raising of fresh capital should prove unavoidable.

[1] Some of the sources are given on p.152.

In our book *Investment in Innovation* we showed what a remarkable variety of methods, rules, guesses, and hunches firms use in deciding whether it is worth while to spend money on the capital investment needed for technical progress. There is in fact no reason why any one method of decision should be used by all firms, for alternative formulations may be more or less equivalent; for instance, one firm may estimate the yield of an investment before tax, and test it against a yield requirement of 20 per cent.; another firm may estimate the yield after tax (including an estimate of any changes in tax), and set it against a yield requirement of 10 per cent. As long as expectations are formulated in a consistent manner in a given firm (and we doubt if they always are), differences from other firms do not matter much.[1]

The rules for making sound decisions about investment in innovation seem to us to be these:

1. There should be so far as possible a clearly defined list of technical possibilities reasonably to be regarded as available for the firm's use—that is to say, developed within the firm, or in process of development; [2] or developed elsewhere, but likely to be available, e.g., on purchase of a particular machine or on payment of royalty. The existence and frequent revision of such a list means that the firm has a policy for 'communication', in the sense described in Chapter 3; for this it needs staff able to understand the relevant technical developments, and to carry out the specialist function of keeping in touch with them.

2. This list will probably contain some projects which, though they must be kept in mind, cannot yet be regarded as commercial possibilities. For the rest, definite estimates in money terms of expected cost and of expected money yield should be made. These estimates should be made even though many of their elements may be, to begin with, no better than guesses; for the exercise of expressing 'hunches' and vague ideas in figures helps to draw attention to the points at which further information should be obtained. On the other hand, the fact

[1] The nature of the formulation (yield or pay-off period) will differ according to the position of the firm: see (4) below, p. 75.

[2] See Chapter 4; the rules here described are, in firms which undertake research or development, related to the rules for choosing research or development projects.

that an estimate is expressed in money terms should not be allowed to give it an authority greater than it deserves. Where uncertainty is particularly great, a range of estimates can appropriately be calculated, or (if a single figure is used) some special note of its uncertainty should be attached. Failure to do this does not enable the firm to dodge the problem of uncertainty. It merely leads to needless surprises, or (more likely) to the inclusion of allowances for uncertainty in a disguised form at some other stage of decision-making.

3. The estimates of cost for an innovation should include the 'dislocation costs' of introducing it, and the cost of any extra working capital required. The estimates of cost for a new product should include the cost of initial advertising. The estimate of yield is obtained from sales forecasts and forecasts of costs. Opinions differ as to whether these should make an allowance for future inflation, or should assume constant prices; the effect of the latter assumption on the margin between sales price and costs is the same as assuming that prices rise by the amount of any increase in costs and no more—i.e., that there is no inflationary rise of profits. In practice, the difference made by an allowance for inflation is not great, unless it is thought likely that sales prices and material or other costs will move in a very different way.

4. The estimated percentage yield (or range of percentage yields) on cost should now be calculated for each prospective development; alternatively, the relation is sometimes expressed as a 'pay-off period' necessary to repay to the firm the cost of the development. Unless the pay-off period is very long, or the cost of raising capital unusually high, it is an unnecessary refinement to 'discount' future yields at the current rate of interest. It should be noted that the pay-off period method may be misleading. Two alternative processes, A and B, might promise the same pay-off period, but if the probable economic life of process A is greater than that of process B, then it would promise a higher true rate of return on the investment. Where the probable life of the asset is required for capital budgeting the pay-off criterion is little use. It is, however, useful if the firm is short of cash and unwilling to borrow, or doubtful about its capacity to do so; for the pay-off period shows the time taken to rebuild cash reserves, and this may be a very important matter to a

firm in such a position. The pay-off period also provides, as we mentioned in *Investment in Innovation*, a crude way of making allowance for uncertainty. A short pay-off period means that the firm risks a cash loss for only a short time; thereafter, if the equipment maintains its earning power, there will be gains. If the future beyond four or five years is clouded by uncertainty, a firm is naturally more willing to undertake an investment if some cash gains are probable before this uncertainty takes effect.

5. The developments can now be ranked in descending order of percentage yield, or in ascending order of pay-off period. The fact that some developments will be shown with a range of estimates, or other marks of uncertainty, will indicate the points at which the Directors must exercise judgement, or take a risk, in deciding what expectation of outcome to assume. Otherwise it is desirable that reason should be shown for departing from the order of priority of developments shown by the list. Such reasons will often exist; for instance, one development may fit in better with the main line of interest of the firm than another which shows a somewhat higher yield.

6. Across the list of expected yields there can be drawn a line, showing the return which the firm can get by investing its resources in securities or in another available line of business. Clearly very strong reason needs to be shown for making an innovation with a yield below this line; or (more accurately) below the line set by the yield obtainable elsewhere *at comparable risk*. In general, however, a much higher yield 'threshold' will be fixed (say 25 per cent. before tax). It is certainly wise to bear in mind that rapidly progressive industries often demand pay-off periods as short as three to five years from their new developments; but we doubt the wisdom of publicizing a particular minimum yield within an organization, lest it should react on the honesty of people's estimates. The temptation to be optimistic about the yield of a project on which one is keen, so as to get it over the limit, would be strong.

In fixing a yield 'threshold', some attention should be paid to yields obtainable or required elsewhere, even if the company has no immediate intention either of borrowing or of lending. But it is possible that if the firm is at a critical point of its existence, at which it must make an investment to stay in business at

all, it should set itself a lower yield criterion; while if it is likely to need external finance, and expects to find it difficult to obtain, it should aim at a higher yield. A fixed arithmetical rule may be misleading.

The systematic procedure described is (with various refinements) that which we have found in some progressive firms. We are aware that it will seem impossibly exact to firms which have been used to deciding investment plans by vague hunches. But this is partly because such a systematic procedure is not created overnight; it starts as an attempt to express existing hunches in a numerical form, but it is steadily refined by successive revisions. Some firms, for instance, have provisional investment plans which are revised at six-monthly intervals (all estimates of cost and yield being re-examined at each revision) and which are carried forward ten or even twenty years from each revision date. Provided it is realized that very substantial changes will take place as plans get nearer the date of their fulfilment, such an exercise in forward planning can be most valuable. It fits in with a proper system of capital budgeting, which helps to show whether investment plans are feasible in terms of present financial resources, and (by proper control of the capital programme) may make it possible to raise funds in good time and at lower cost.

The exercise requires the co-operation of research and development departments (if they exist), production departments, and the sales department. The staff engaged in research and development is encouraged to look ahead not just at the possibilities which are scientifically interesting or exciting, but at those which fit in with the commercial objectives and resources of the firm. The need to provide sales forecasts will improve market research, which is weak in many British firms; the need to produce estimates of production cost will improve cost-accounting methods. Finally, since the estimates require co-operation between several departments, their compilation will encourage the habit of discussing problems jointly, which is important to the satisfactory technical progress of the firm.

The rules we have given require some elaboration where the problem is one of replacing an existing machine or line of production, rather than of adding a new one. This is a point at which accounting habits are liable to over-ride common sense.

If a machine is still working, it is irrelevant if it has been written down to nothing in the books of the company; the reality is that it still has a useful life before it, and therefore retains some part of its original real value. The original depreciation allowances have been shown by experience to be excessively prudent, and the progress of inflation may mean that they have an out-of-date price basis. The first step, therefore, is to reassess the remaining value at current prices of equipment to be displaced, and the costs of continuing to work it. The choice should be made between 'old type' equipment as though it had been newly acquired at a second-hand price, and new equipment.

The real test is the additional net earning capacity of the new equipment. If this shows a high enough yield, in relation to the cost of finance and the alternative uses for funds, the old equipment should be scrapped even if little of its value has been written off. This is a point at which firms run the danger of forgetting the arbitrary assumptions of accountancy. Those firms which make depreciation provisions which are demonstrably excessive run the risk of misleading themselves by showing a jump in profits at a later date, which is produced by an accounting convention; at the same time, they make it difficult for themselves to instal new and improved capital equipment, because they become over-impressed by the effect on the firm's accounts of replacing an asset standing at zero value by one at full replacement cost.

This, however, is not all that needs to be said. A firm must also ask itself what difference continuance of old methods or old products will make to its competitive position. It is rare for technical change in a process to leave the product wholly unaltered. The firm should therefore ask itself—even if (on the face of it) it is not profitable for us to adopt this innovation, assuming current sales, will any of our competitors do so? Will they thereby so cheapen or improve the product that we shall have to make a radical revision of our sales forecasts? The answers to such questions may clearly suggest that an attempt to continue with the old method will in fact be gravely unprofitable.

A monopoly is apparently free from such pressure towards quick obsolescence; but most so-called monopolies are in fact subject to serious competition from alternatives. Thus it is

necessary that the speed and comfort of rail travel should be increased, and its cost held down, if it is to hold its own against better cars running on improved roads. It is true in many trades of differing degrees of competitiveness, that equipment becomes obsolete long before it is worn out.

CHAPTER 8

What Innovation Requires from Management

THE earlier chapters sufficiently illustrate the fact that technical progress involves changes in the thinking and practice of management. The firm may need to introduce new management techniques (Chapter 2); the communication of ideas will require attention (Chapter 3); good procedures for making decisions about investment will be needed (Chapter 7); the complex management techniques of research and development may have to be brought into the firm, and may in turn create problems for other departments (Chapters 4–6). This chapter rounds off Part I by giving further illustrations of the impact of innovation on management structure and management methods, and then turns to consider in general terms how the managers and technical personnel, needed to create and supervise changes of product and process, should be recruited and trained. Thus we arrive at a central problem, for innovation depends on having men of the right ability in the right place, and progress must be slow if proper attention is not given to finding these men and to training them.

The desire to innovate may affect management structure directly, by making it necessary to create a new department to undertake research and development. When this department produces results, or when new ideas are brought in from outside, further changes of structure may be needed to provide for the management of the innovations. Thus Burch's work on high-vacuum equipment for the Metropolitan Vickers Electrical Co. (p. 24) led to the development of special X-ray equipment; a new department was created to produce this on a commercial scale, and in order to manage this novel line of production appropriately a number of those involved in the research and development were appointed to senior positions in the

new department. If a new product is to be made in a separate factory a more complex change of structure may be necessary, because geographical separation lessens the co-ordinating influence of the managers at the main factory. The manager in charge of the product at a new branch factory may need room to exercise more discretion and may have to carry more responsibility than managers of similar departments at the main factory. Obvious though this point is, the failure to recognize it has often led to disappointing results.

The introduction of a new product may also have a big influence on the sales department, and on its relation to other departments. With certain technical products 'customer education' is an important part of selling, and this may call for the provision of a great deal of technical advice to customers. Staff from the research, development, or production departments may have to be brought in from time to time to help the sales department to convince potential customers of their need for the new product, or of its technical superiority over its rivals. This is particularly likely to happen in such cases as electronic products or aircraft, and in the industries making these the help of the research or development staff may be needed to estimate market trends, often through the process of 'selling ideas' to possible future buyers.

But innovation not only changes the structure of departments and their relations with each other; it also tends to change the relation between grades of management and the whole pattern of lines of communication and authority within the firm. As the technical complexity of production increases there is likely to be an increase in the ratio of the numbers of managers and supervisory staff to other employees, in the number of levels of authority in the management hierarchy, and in the span of control of the chief executive.[1] The introduction of an 'assembly line' provides a good example of how a change in methods of production influences management structure. The assembly line in a motor-car factory runs through a number of different 'departments', and it creates a high degree of interdependence between workers and between foremen in the different departments. In other words, the assembly line creates strong

[1] Joan Woodward, 'Management and Technology', *Problems of Progress in Industry*, No. 3, D.S.I.R.: H.M.S.O., 1958.

horizontal ties between departments, which may be contrasted with the *vertical* ties shown on the usual management charts of superior–subordinate relationships. Foremen on an assembly line may work, not through the official vertical structure, but by creating informal co-ordinating relations with other foremen. Instead of simply sending up to superiors information about faulty work earlier on the line, irregular supplies of parts, or the need for engineering services, they may often need to deal directly ('horizontally') with other foremen and ('diagonally') with the handlers of materials and with maintenance men, so as to prevent delays or a piling up of faulty work. Some of these needs have been recognized and formalized. Thus on motor-car assembly lines provision is made for a line worker to signal directly for maintenance men, and in a more complex case the flow of parts to the various stations on the assembly line is directly co-ordinated with the flow of models. But not all non-vertical management relations have been formally recognized, and failure to develop them informally often leads to delays and to personal friction between foremen.[1]

New methods of production react on management structure; and bad management structure reacts back on the effectiveness of production, and may lead to a wrong assessment of the value of a new product or process. For instance, an automatic mill for producing seamless pipes, installed by a large American steel corporation, produced below estimate for almost three years because of a failure to recognize a new relation between the so-called 'direct' and 'indirect' labour. Although the machinery is called automatic, production is much affected by 'downtime', which occurs when the mill has to be repaired or reset for a different size of product. However, the 'downtime workers' were treated, according to usual practice, as non-productive or indirect labourers. They were not under the direct control of the line managers, and in contrast to the mill crew they were paid day rates. It was this conflict between the old management

[1] See Charles R. Walker, Robert H. Guest, and Arthur N. Turner, *The Foreman on the Assembly Line*, Harvard University Press, 1956, and F. J. Jasinski, 'Adapting Organisation to New Technology', *Harvard Business Review*, Vol. 37, No. 1. The need for these horizontal relations between production departments arises from failure to conform to details of the production schedule; this is a different problem from that of the horizontal relations required for good research management, as discussed in Chapter 5.

arrangements and the new technology which explained the unexpectedly low levels of production. There was a great increase in production after the management had accepted arguments by the mill crew that repairs would go faster and be done better if the incentive-bonus plan were extended to the entire work group.[1]

Discussion of the relationship between productive techniques and management methods has been centred especially on the group of developments loosely described as 'automation',[2] which seem especially likely to require a radical change in the way in which business is organized and staffed. Automation, according to Diebold, 'is a new way of organising and analysing production, a concern with the production process as a system, with each element as part of the system. It is something of a conceptual break-through, a whole new philosophy of design and production, as well as a new technology of machine control. It will, in the end, have an even more widespread effect on business and industry than Henry Ford's concept of the assembly line.'[3] Though many will not be disposed to adopt Mr. Diebold's apocalyptic view of automation, his list of 'the kinds of change experience with automation has proved to be necessary' is of general interest. He maintains that:

'(1) Machine maintenance should be directly under the manufacturing superintendent responsible for the automation line, rather than under the plant maintenance or plant engineering departments. The special skills and training required to keep such facilities operating necessitate this change.

'(2) The product engineering department should include a production or automation engineer to ensure that automation manufacturing principles are observed in the product and parts designs. One approach to meeting this need has been to make the project engineer for the product responsible for all aspects of its production, from design to manufacture, and to include a manufacturing

[1] See Charles R. Walker, *Towards the Automatic Factory*, Yale University Press, 1957, pp. 126–42, and 'Life in the Automatic Factory', *Harvard Business Review*, Vol. 36, No. 1. See also A. K. Rice, *Productivity and Social Organisation, The Ahmedabad Experiment*, Tavistock Publications, 1958, for an account of operational research concerned with the interaction of social, economic, and technical change in an Indian textile mill.

[2] See *Automation*, D.S.I.R.: H.M.S.O., 1956, for a useful discussion and list of references.

[3] 'Automation: a break with the past', *Times Review of Industry*, April 1958, p. 10,

engineer on the project staff. This is typical of the "job expansion" approach that is gaining widespread acceptance in other areas of industry. Another approach is to delegate final product design responsibility to a committee which includes a manufacturing or automation engineer.

'(3) The process engineering and tool engineering functions become so interrelated that a single manufacturing engineering function is better suited to the needs of automation than a system that tries to keep these functions separate.

'(4) Manufacturing department organisation by function or machine grouping is often no longer practicable. The department, if subdivided at all, should be organised by product line or part line, with all functions related to a particular product coming within one group.

'(5) Those responsible for the automation planning and engineering functions should report directly to a high level of management.'

The first of these has already been illustrated by the example of the pipe plant. The second, an argument for including an automation specialist in the production engineering team, is simply a special case of the general interdependence (examined in earlier chapters) between research, development, production, and sales. The fifth proposal is a reminder of the need to keep 'top management' fully aware of the impact of new methods on all aspects of the business. Of the other suggestions, the fourth calls for comment. It proposes that management should be shifted from a process to a product basis, and appears to be an attempt to make the pattern of management agree with that of technology, by making the manager of a product line take charge of a series of linked processes. This is a workable solution if the number of workers on the whole product line is small enough to lie within the span of control of a single manager—as may well happen with a high degree of automation. But if a manager has to control a great many workers, he will require several levels of intermediate management beneath him, and the tasks of the sub-managers may well have to be defined as covering particular operations or service functions. This means that there is no simple way of dodging the need for having both vertical and horizontal relations in the management structure.

The automation example brings out the inter-relation of management structure and technology in an extreme form, but

the problems of this inter-relation are general, and it is important that firms should identify and face them. Thus if, in a large assembly line, the supervision of a group of related functions is split up because one man cannot effectively cover the whole lot, it will be helpful to identify the informal horizontal and 'diagonal' relations which are likely to emerge. The company may be able to help the growth of these relations, and to lay down rules to guide the various levels of management in making use of them. A committee, such as the development committee proposed on p. 54, can help to establish horizontal links between departments, but sympathetic informal communication between individuals will also be needed; co-ordination cannot always wait for a committee. A big project may have to be lifted out of the normal management structure, and put under a special manager with direct authority over specified individuals and facilities, until the 'teething troubles' have been overcome and the normal structure can be used without impeding progress.[1]

The right way of adapting management structure to a particular innovation cannot be laid down in detail in advance. Urwick [2] has suggested for management a *Principle of Definition*, namely the clear definition of 'the content of each position, both the duties involved, the authority and responsibility contemplated and the relationships with other positions', and a *Principle of Correspondence*, namely, 'the correspondence of the responsibility and the authority of every position'; but these are fully workable principles only in a static world with no untidy new ideas. Where innovation is an important part of the activity of a company some room must be left for the informal growth of new responsibilities and of new relations between managers. The General Manager of one company noted for its innovations maintains that if all duties were clearly defined no one would do more than his defined duty and the company would become stagnant. This is an exaggeration, but his main point

[1] A parallel problem is that of introducing a new process, such as (for instance) an automatic plant. It may take time to get the new plant working efficiently. As a consequence piece-rate earnings may be low just when the operatives must make their adjustment to the new methods. This may incline them to be unco-operative at a time when their co-operation is most needed. One way to meet this problem is to have a task-force of highly trained technicians to take over and run the new plant until 'the bugs are out of it'. See Walker, *Towards the Automatic Factory*, p. 115.

[2] Quoted in Brech, *Organisation, the Framework of Management*, Longmans, 1957, pp. 386–7.

is that technical innovations create problems of management which are not always predictable, and that unless there are able and enterprising managers prepared to assume new responsibilities in advance of a formal grant of authority the management structure would prove to be too rigid for efficiency. The management of innovation requires a penumbra of uncertainty about the rights and duties of managers. It is in this penumbra that there is room for initiative and enterprise from the lower and middle ranks of management, which can be valuable in speeding up technical progress. Recognition of this does not, however, absolve top management from all attention to the Principle of Definition, for if managers go on adding to their responsibilities there may come to be a conflict between defined and actual responsibilities which would simply create inefficiency and bad feeling. There must be some order and there must be some flexibility; to get both it is necessary to review the structure and processes of management from time to time, so as to adapt them to changing needs. Sometimes it will be appropriate to recognize new-grown responsibilities by the grant of authority; sometimes it will be appropriate to redistribute responsibilities. Although in this review the Principles of Definition and Correspondence should be re-asserted it should be done in such a way that managers will still be able to adapt their tasks quickly as new problems emerge.[1]

The need for flexibility deserves special attention. The good management of a changing situation is a combination of planning to meet predictable situations and preparedness to meet the unexpected. Managers should naturally try to predict as much as possible, so that they can plan for it—and good prediction grows out of a sound knowledge of what is going on in

[1] An account of the weaknesses of a mechanistic system of management in the electronics industry is given in T. Burns, *Management in the Electronics Industry*, Social Sciences Research Centre, University of Edinburgh, 1958. Burns comments that: 'With expansion and technical innovation proceeding at their present rates, new problems and managerial responsibilities were bound to be frequent and largely unpredictable. In such circumstances, to operate with a clearly designated array of functions and responsibilities meant that any new feature of the total task of management could not be tackled until the Managing Director had become aware of it and allocated it to some one person or created a new functional position; a rigid structure, indeed, in which everybody knew his job and his authority and responsibilities and—what is more important—was clear about what he did *not* have to bother with, was liable to run into recurrent crises' (pp. 27–28).

the firm *now*. But prediction is always imperfect, and it is important to create a management structure which will not be upset by sudden unexpected changes of circumstance.

It takes good men to manage a changing situation. The qualities they need are of two kinds: the capacity for responsible initiative, and the possession of understanding and competence growing out of a knowledge of one or more management techniques. In a changing situation managers may have to take new responsibilities; but they must take this initiative sensibly, lest it should degenerate into mere empire-building, of no help to the progress of the firm. Generally the useful exercise of initiative will require the use of acquired technical or managerial skills. Thus management selection is more than a search for personal qualities of poise and capacity to lead; it is also a search for specified skills.

In analysing our case studies we found that the technical progressiveness of firms was correlated with their willingness to recruit staff with good education and training, and also with the degree of their interest in the further training of staff. The management structure of progressive firms made adequate provision for intermediate managers of good quality (between top executives and the shop-floor supervisors) and thus incidentally provided a ladder of promotion and an additional means of training. The technically progressive firms were attractive to talented staff, and having recruited them, these firms were often able to bring the best out of them by avoiding occasions of frustration. Scientific and technological staff were well integrated into the firm and had a high status; the team-work of departments, in planning a new development, was effective. Unprogressive firms tended to restrict recruitment to those leaving school at 15 or 16, except for the occasional professional recruit, such as an accountant; they confined training to a minimum (supplemented by vague admonitions to 'go to night school'); they provided no satisfactory ladder of promotion, they tended to frustrate any talented people that they managed to attract, and scientists (if they were employed at all) were shut away in a back room and not made an effective part of the managerial team.[1]

[1] *Industry and Technical Progress*, pp. 180–2. See also our article, 'The Characteristics of Progressive Firms', *Journal of Industrial Economics*, March 1959.

These results are what one would expect if the 'output' of advances in technique, duly applied, is related to the 'input' of high-grade technical and managerial ability; but this relation is not a simple one. In a number of firms known to us technical progress has depended on the drive, vision, and ability of one man; and no improvement of recruitment or training methods would be adequate to produce rapid technical change, unless it succeeded in filling the key position with the right man. Our informants have spoken of the desperate shortage of people of really first-class ability and character to fill such key positions—a shortage which appears to some firms to be far more serious than any shortage of finance or of subsidiary personnel. We have little doubt that there is an absolute deficiency of first-class ability, and that this sets an upper limit to the speed of technical progress. But this is not usually, we think, an effective limit at present. Many firms could be more receptive to new ideas, and better at making them ready for use, if they gave more thought to the identification, training, and development of talent, and to strengthening their technical skills by co-operation with consultants, research institutes, technical colleges, and universities. Many firms (especially among those which can advance by picking up knowledge already developed elsewhere) do not need exceptional ability so much as an infusion of ordinary technical and managerial competence. In these firms there will be a reasonably direct relation between the degree of trouble taken over recruitment and training and the pace of technical advance achieved.

As part of their programme for the development of management, all firms should have a conscious plan for the recruitment of managerial and technical staff, revised at frequent intervals but at all times looking ten years ahead. The plan may be only rudimentary, and it may be suddenly upset by death or removal; it cannot be a forecast of what *will* happen, but only a set of ideas for dealing with what is reasonably likely to happen. Such a plan is more necessary for small firms than for large, for a large firm has more chance of meeting emergencies by internal adjustment. It is not difficult to find small firms which are running efficiently under a Managing Director who will clearly have to retire within ten years; and yet no successor is in sight, and the firms have no scheme of promotion and training which

can produce an adequate successor. Such firms would do well to ponder the following statement of the principles of selection used by the Industrial and Commercial Finance Corporation: 'In looking at propositions, we pay special attention to management and we attach special importance to evidence that continuity of management is provided for. We are not the only financiers who realize that what one really invests in, whatever the business, is flesh and blood rather than buildings and machinery'.[1]

The recruitment plan should be based, not on the existing structure of management and use of scientists and technologists, but on the state of affairs which it is desired to achieve; and, to define this, the firm should look at the best practice elsewhere in the industry, and where possible at practice in other lands. A decision must be taken on whether it is desirable to commence, or to expand, research and development work; and we have said something in Chapter 4 on the factors which should influence that decision. Even if no new research and development activity is contemplated, it may well be that, in the normal course of change towards a greater use of science, more scientists and technologists will be needed in the sales and production departments, or in general management. If the scale of the firm's activities is expected to increase, or their scope to change, there may be a need for more managers, and perhaps for new levels of management. (At this point the capital budget and the recruitment plan should be co-ordinated with each other.) The improvement of management techniques recommended in Chapter 2 may involve the creation of specialist posts or departments, e.g., for work study or cost accounting. An examination of the work-load of senior executives may show that they are over-burdened with routine, and that a strengthening in lower levels of management is needed.

Having thus made a rough estimate of new needs, the demands for replacement of existing staff should be estimated, on plausible assumptions about turnover and dates of retirement. (If, at this point, it appears that in the past turnover of staff has been very high, it may be worth considering whether there are reforms which, by reducing frustration, will lessen turnover in the future.) The plan should next be examined to see if it is

[1] Lord Piercy, *Business Finance*, Institute of Directors, 1958, p. 18.

consistent. Does it provide a variety of continuous routes, or 'ladders', from first recruitment to the highest managerial and technical positions? Are there men placed at suitable intervals on these ladders? It is not, of course, possible or desirable to dispense altogether with recruitment from outside for senior posts; organizations which attempt to do so are liable to become very inbred. But if the plan contains numerous gaps, and thus theoretically involves a large reliance on outside recruitment for senior posts, the result in reality may be that unsuitable and incompetent persons will be promoted within the firm.

The complete and consistent plan yields a first estimate of recruitment needs, classified according to the types of experience or technical competence required. ('Qualified cost accountant probably needed before 1965: qualified electrical engineer, 1962: trainees for general management, one in each of 1960, 1962, 1964, 1966 . . .' and so on.) This will, of course, require constant revision, and it will be a definition of likely *demand* only. There may still be alternative methods of *supply*. Thus a management trainee may be the Managing Director's nephew, recruited from a public school at 18, or a promising office boy or apprentice, originally recruited at 15 but (at age 21) considered worthy of being promoted to the staff, or a graduate recruited at age 22. What is there to be said about alternative methods of recruitment?

First we must consider the family firm, by which we here mean a firm which is managed as well as owned by members of a single family. Except for those born into the fragmentary remains of the landed aristocracy, the members of business families are almost the last group of those who can hope to be greatly assisted in attaining wealth and position by the advantages of birth. The social virtue of the small family firm, in the paternal relationship of the ruling family to the workers, remains important in some cases; but like other such feudal relationships, it tends to be broken down by the greater mobility of workers between districts, and by the lessening acceptance of class barriers. It is sometimes argued that a man will do his business better if he is working for his family than if he is working for his own salary and the profit of unknown shareholders; but this seems to us an uncertain argument in the present state of knowledge about incentives. Thus the advantages of the

family firm are mainly private, within the family; and they have to be set against several potential public disadvantages, whose effect is such that a family firm 'requires unusual luck to remain vigorous and progessive'.[1] There is little evidence that business ability is hereditary, and that the son will merit (or even be happy in) his father's position; those family firms which continue vigorous through several generations are often governed by very large interlocking family groups, from which the best representative can be chosen in each generation. There is little evidence that the upbringing of the sons of business-men is especially likely to fit them to succeed their fathers; they may, of course, be bred in the atmosphere of the business, but to attain easily what their fathers won by a long struggle is not a good preparation for a competitive world. Again those family firms which continue vigorous are often found to give a great deal of attention to securing the right technical training and outside experience for their younger members, who are made to realize that merit as well as influence will determine their position. The financial problems of maintaining family control, despite large death duties, often result in the business being starved of capital which it needs for its development. Finally, a business in which the higher positions are reserved for members of a ruling family must expect to find it difficult to recruit or to retain talented people for junior managerial posts, since they will soon realize that promotion beyond a certain point is blocked.

A decision to continue to recruit from the family for senior positions is thus potentially a decision to put private before public advantage—the advantage of the smaller social group before that of the larger. In some cases the issue is unimportant—for instance, in a small-scale, competitive industry whose tasks are mainly of a routine kind, or determined from outside the industry. It is not a matter for public concern if a garage proprietor chooses to be succeeded by his son, for technical progress in the motor-repair trade will be enforced either by the suppliers of cars, fuel, and accessories, or by competition. In some cases the public disadvantages can be overcome, and there are many quite large firms with a degree of family management which continue highly progressive. What is important is that the choice to continue family management should be made with

[1] See *Industry and Technical Progress*, pp. 123–4.

an absolutely clear appreciation of the dangers, and with a vigorous effort to overcome them. This means that no post should go to a member of the family unless it is reasonable to suppose that he would get it on qualifications and ability alone; that special efforts should be made to give younger members appropriate training and outside experience; that reasonable consideration should be given to the acceptance of outside capital, and that some posts at all levels should be open to non-members of the family chosen on merit.

If managers and technical staff are to be chosen from an open field there will be no dispute that they should be chosen on grounds of ability. Many firms in the engineering industry, and many unprogressive firms in other industries, consider that this ability is best identified by recruiting apprentices and clerks at age 15 or 16 and bringing up a selected few as managers 'the hard way', with the consequent thorough and practical knowledge of every department of the business. It is clear that this line of promotion for apprentices or clerks should exist; no man should be debarred from advancement because he has left school early. It is clear also that those who leave school at the minimum age include some of considerable ability; early leaving from school may be due to social pressure, parental circumstances, bad schooling, or late recognition of ability. Nevertheless, it must be true that the proportion of high ability among those who leave school at the minimum age has been considerably reduced by the extensions of secondary and higher education since 1945. The trend towards later school leaving is continuing, and a firm which confines its normal recruitment to young apprentices and clerks is taking a most unwise risk.

The larger companies in many trades have, in fact, established several channels of recruitment for managerial and technical jobs: from the factory, taking bright apprentices who have proved themselves in National Certificate or other courses; from schools at age 18; and from universities. To obtain staff of special qualifications or ability, they insert expensive and seductive advertisements in the Press, and send speakers and interviewers to schools and universities. But we find that many smaller firms are weak in the technique of recruitment, confining themselves to inserting advertisements in the papers, which sometimes lack conviction because they ask for an im-

possible combination of qualifications and experience or offer a salary below the market rate. If a graduate is needed, it is not particularly difficult to circularize twenty University Appointments Boards, and to have good personal contact with at least one of them; if, in addition, there are good contacts with relevant university departments, it may be possible to get early personal recommendations of graduates believed to be looking for a job. The staff of Technical Colleges, the professional institutions (some of which maintain employment registers), the Public Schools Appointments Bureau, local headmasters—these and others can help with recommendations. If public advertisement is to be used, it should be only after a consideration of what qualities it is reasonable to ask for, and a comparison with what is being offered by other firms. We must apologize for making points which are so obvious. Obvious as they may be, they are not yet part of the practice of some firms.

It will often be necessary to make a choice between recruiting a youngster, and training him during his first few years of employment, and recruiting a man of experience trained in another firm. On the whole, large companies, knowing that they cannot rely on getting technical and managerial staff from elsewhere, set up their own training schemes. These often have an intake in excess of the company's needs, so that after a few years those who have proved unsatisfactory, or who prefer a different environment, can be encouraged to move to another employer. Many small firms, and a few large ones, are parasitic upon the companies which thus do more than their fair share of training; they reckon to recruit staff endowed with experience and fully-trained at someone else's expense.

Sometimes this arrangement is satisfactory to both sides. It does not follow that the man who wants to leave a large company after five years is a failure or a likely misfit in any firm. He may be a person of vigour and originality who is tired of the complexity and the slow promotion of a large organization. There are many who welcome for a period the efficient training and the choice of experience offered by a large organization, but who are temperamentally best suited for the freedom of a small company. But we are inclined to think that there are too many firms which are parasitic in obtaining their managers and technologists, that they run unreasonable dangers, and that an undue

burden of training is placed on the large, progressive companies. The dangers are that the 'parasites' will receive, mixed with those who have good reasons for moving, an undue proportion of the congenital misfits; and that they will miss the really first-rate people. Unless the firm which offers training is singularly wooden in its personnel policy, it will be able to recognize and retain a large proportion of the outstandingly good people.

The desire to recognize and retain the first-rate is one reason why good training schemes are found in technically progressive companies. Obviously the nature of the training scheme possible varies with the size of firm, but we do not think that any firm, however small, should regard staff training as beyond its scope. It should be a deliberately organized activity, planned in collaboration with local technical colleges, schools, and universities, and representing an expenditure consciously undertaken to obtain certain advantages—the chance of retaining someone first-rate, the greater certainty of adequate provision for filling future vacancies.

For scientists and technologists, and also for technicians, staff training is an extension of apprentice training; it involves such things as day release for technical-college studies, release for sandwich courses, and perhaps the provision of scholarships for full-time or part-time studies at a university. It is possible that the provision of scholarships to enable selected boys and girls from poorer homes to remain at school until a later age may be worth considering. A few companies undertake the theoretical part of technical training in their own schools. Training for management usually involves periods of experience in different departments, and release for studies at a technical college—e.g., in work-study courses, or to obtain professional qualifications in cost accountancy. Some companies, again, have management-training schemes in which theoretical as well as practical knowledge is taught within the firm.

A number of schemes have appeared in the engineering industry for the joint training of craft apprentices by a group of smaller firms. Though the difficulties may be greater, it is worth considering whether the same could not be done for management or technological posts. For instance, one firm (in co-operation with a technical college) could take responsibility for staffing work-study courses open to all in the area. (Some

experiments of this kind already exist.) Training in sales management and other managerial techniques might similarly be the special responsibility of particular firms; and firms with particular technical facilities (e.g., those using radio-isotopes) might offer training facilities. At the managerial and technological level the difficulty about such schemes would probably be the fears of discovery of trade secrets. It is therefore worth repeating that secrecy about techniques of production is a characteristic of unprogressive firms, but is much less often found in progressive firms.

The variety of local circumstance is so great that it would be foolish to lay down more precise ideas about training. The main point is that it should be an activity consciously undertaken according to a long-term plan. It is not enough simply to hope that employees will better themselves by evening study; they must be given a fair chance to study, and an incentive to do so. In some industries joint action through a trade association is needed to remedy a general shortage of technical training facilities—e.g., by pressure on local authorities to improve technical colleges, by offers of the release of staff part-time for technical-college teaching, or even by the establishment of a special trade college.

It is possible that smaller firms are discouraged from taking a keen interest in training because they fear the trouble and expense which it will cause. It cannot, of course, be entirely free from expense; but for any firm which is within reach of reasonable technical-college facilities, it is an activity whose expense is largely carried by public authorities, and the remaining 'private' expense (e.g., the loss of the services of employees while they are attending sandwich courses) is commonly small in relation to the potential benefits. We suggest that firms which are thinking of taking a more active interest in training should first consult the Principal of their nearest Technical College, and also obtain relevant introductory publications from the British Institute of Management (e.g., *Management Techniques in the Smaller Enterprise*) and the British Productivity Council (e.g., *Better Ways*). Having made these contacts, it may be wise to obtain the advice of a management consultant on the techniques which might be used in the firm, and the consequent training needs (for some of which the consultant may be able to offer

direct help). The British Institute of Management maintains a register of consultants.

Recruitment, training, and the adaptation of management structure are three related activities, and a firm which desires to be technically progressive will find it necessary to take them all seriously. It is no use recruiting good managers and training them if their ability is to be wasted and frustrated by an inappropriate management structure. It is no use having a good structure on paper if there is no satisfactory means of recruiting men to fill the various positions. Management must be organized so as to use to the full the ability which the firm can, by sound policy, attract to its service and train for its needs; and this will not be achieved unless management structure is brought under regular review and adapted in readiness for the future technical opportunities and the future growth of the firm. The greater the intended rate of innovation, the greater the need for planned management development; and time, thought, and money spent on its three aspects—recruitment, training, and adaptation of structure—will usually be found to be 'good business'.

Part II

ACTION BY GOVERNMENT

CHAPTER 9

The Strategy of Government Aid

In this second part of our report we turn to consider some of those instruments of policy by which the Government can help and support technical progress, and some of those instruments which (though designed for other purposes) may incidentally speed up or hold back the advance of technique. We have earlier concluded [1] that

> 'the net effect of Government action on the rate of adoption of new scientific and technical knowledge must be strongly favourable. The education of scientists and technologists is predominantly State financed, and much of it is so expensive that it would be beyond the resources of individuals. A significant part of the country's research effort, including such vitally important fields as nuclear engineering, is to be found in Government laboratories. The research associations and research stations draw on Government funds. The Department of Scientific and Industrial Research has a great record in the encouragement of science.'

This Government help is the concern of many different Departments and State-sponsored bodies, while other Departments use instruments (for instance, Purchase Tax) which may incidentally hinder the adoption of new techniques. Some of the present organization by which the Government assists technical progress is briefly described at the beginning of the next chapter. For our present purpose, it is sufficient to observe that the Lord President of the Council holds responsibility for 'the formulation and execution of Government scientific policy', and that since January 1947 he has had the help of the Advisory Council on Scientific Policy, a body of most distinguished membership. This Council is the successor to the Scientific Advisory Committee to the Cabinet, set up in 1940; and it is thus related to the lively interest in scientific matters shown by Mr. Churchill in

[1] *Industry and Technical Progress*, p. 174.

his war-time Premiership, and to his appointment as his personal adviser of Professor Lindemann (the late Lord Cherwell).

The Lord President's responsibility is clearly meant to imply a Cabinet interest, that is to say a need for a general 'Government scientific policy' which is something more than the mere addition of the policies of separate Departments. The effectiveness of this general interest varies with the structure of Government—whether it is tightly controlled by a small inner group or run with a large amount of departmental autonomy. This structure shows frequent and subtle changes, both in its formal expression and in the concealed interplay of personalities. It is not therefore very easy to find out what a 'Government scientific policy' is meant to be. The reports of the Advisory Council are in part taken up by advice on miscellaneous questions, often cutting across departmental interests, which had been referred to or brought to the attention of the Council. Typical questions have been: toxic substances in consumer goods; the future of seaweed research; a central mineral-processing laboratory. But the main subjects of the Council's labours have been: the organization of Government-supported scientific research; the demand for and the supply of scientific manpower, including the related educational questions; and the narrowing of the gap between scientific discovery and industrial output.

The consideration of such matters necessarily raises more fundamental questions. What is the proper place and the right limit for Government action in speeding the application of science? What should be the scale of Government effort? Should it be concentrated or widely spread, and, if concentrated, which should be the points of maximum effort? It does not fit the practical and empirical British tradition to be very clear in answering such questions. It is possible, however, to suggest some general principles to be followed in the search for the answers.

Technical progress, as we have seen, depends on a well-balanced provision for pure or fundamental research, for applied research and for development. The conduct of each of these stages, and also the effective transition of ideas from one stage to another (and finally to actual use in production), depend on the existence of trained scientists and technologists. In this sense the most fundamental part of all Government aid to

technical progress is the support of training facilities. In so far as Government goes beyond this, and gives direct support to one or more of the stages of research or development or application, it should have regard to the need for balance between the stages. Thus there is no advantage in piling up research facilities if the weakness in the application of science to industry lies in the development stage.

Hardly anyone would now question the necessity of support from Government and local authorities for almost all the educational system, including the universities and technical colleges. Other forms of Government aid to technical progress are taken for granted as familiar parts of the British way of life; they include the support of fundamental research in the universities, the extensive research and development required by the defence departments, and a considerable interest in medical research. It is probably also generally accepted that the Government should on occasion fill in gaps or strengthen weak places in the national provision for research and development.

But if one tries to give the idea of 'filling in gaps' greater precision, or to consider what other action the Government might take in aid of technical progress, it becomes apparent that the answer depends on some general decisions of political principle. At one side stand those who look forward to a general extension of State ownership of the means of production, and to whom, therefore, an increase of Government-sponsored research, development, or production is an appropriate and permanent part of this general process. At the other side are those who would seek to confine Government intervention in economic affairs to a minimum, and who are therefore likely to be suspicious of any aid other than temporary 'pump-priming', the starting of a process which private enterprise will later carry on for itself. This is not the place to argue the merits of these views, or of all those views which lie between the extremes; but it is possible to say something about the kinds of action in aid of technical progress which are likely to appear appropriate, whatever the political outlook of the Government. That outlook is likely to affect the scale or permanency of the action rather than its objects.

The most obvious cases for Government intervention are those in which an opportunity for the application of science

creates problems which are on too large a scale for the industries concerned. Thus the cost of research and development may be very high in relation to the resources of the existing firms; or the adoption of the new scientific knowledge may imply a massive investment in plant, or a great concentration of scientific talent, of a kind which the existing firms are unlikely to achieve; or the time-period before results can be expected may be too long for the patience of private enterprise. The development of atomic energy would provide an example even if it had no military applications, for it is an enterprise too vast to fit into the framework of private industry. Similarly the Government financing of most agricultural research can be justified because there is little chance of getting work on the necessary scale done either by individual farmers or by co-operating groups of farmers. In all such cases of incongruity between the scientific opportunity and the institutions of the industry, the possible choices before the Government are either to help the institutions to change so that they may meet the opportunity, or to take direct action to carry out the function which would otherwise be neglected.

Other cases for intervention may arise because of a real or apparent difference between social and private benefit. Thus in a craft industry it is often extremely difficult to convince a firm that it will obtain any financial benefit from an attempt to put its processes on a scientific basis. The costs of such an attempt are apparent, but the rewards are hidden from a firm with no previous experience of scientific industry; and the scales will be weighted against the change because of the firm's uncertainty about its ability to undertake a new kind of work requiring unfamiliar skills. Similarly, each company in a highly competitive industry of small firms may be so dominated by the immediate state of the order-book as to be unable to see the benefits of a long-term policy of research. But in both cases it may be greatly to the national advantage that research and technical change should proceed. Government efforts to change such a situation can take many forms—for instance, 'helping those who help themselves' through a Research Association grant; giving the stability necessary for long-term planning, by a period of tariff or quota protection; giving special financial inducements through subsidies or tax remissions; helping to change the attitude of the industry, through special support for appropriate

technical training, the direct intervention of a Government research station or a Government producing enterprise, or the stimulus of a development contract.

Thus far it will be apparent that there are many points at which Government action (beyond that already taken for granted) might be undertaken, and many forms which this action might take. The present pattern of Government intervention in favour of technical progress has been formed haphazard from a number of pieces shaped by past history. We doubt if it can be said that a Government policy on the application of science really exists. The facts on which such a policy should be based have never been collected or assessed. Substantial research is needed; the right answers will not be reached by eminent scientists or economists in a few days' work in a Government committee, nor will they naturally arise from the present organization of the Departments concerned. This is because the problem is both technical and economic, and it requires extensive and continued study by a group containing both scientists and economists. We do not think that such a group exists at present; and without it policy-making tends to go no farther than a statement of generalities.

We wish to stress this joint nature of the problem, because scientists and technologists are naturally attracted to what is scientifically elegant or exciting, and need the cold reminder that the money might be better spent another way; and economists tend to plan forward from the experience of the past, and to be ignorant of the possibility of sharp changes in cost conditions. We have referred in *Industry and Technical Progress* to the importance of 'cost- and profit-mindedness' in the planning of a firm's research, and we think that the same attitude is important at the national level.

We wish to stress the need for a great deal more patient fact-finding. The gap between basic scientific knowledge and industrial application is a large one; it often takes ten or twenty years, the expenditure of much money, and the use of much scarce ability to pass from discovery to application. It is no easy matter to assess in economic terms the ultimate outcome of an attempt to apply some particular piece of basic science. Risks must always be taken, and wrong decisions will certainly be made. In the absence of the joint technical and economic fact-

finding and assessment, such as we describe, the risks of giving substantial Government help are unreasonably great.

Whatever the results of the fact-finding, it is clear that some opportunities for Government help will have to be neglected in favour of others. This need for choice cannot be avoided; even an advanced nation of fifty million people can no longer take a leading position in all the many fields of science and technology. But differing views can be taken about the degree and nature of the policy of concentration. Should help be concentrated at weak points, or should it be designed to make strong points even stronger (the policy of 'reinforcing success')? Should there be a high degree of concentration, intended to achieve a 'technical break-through' on a limited front, or is it the duty of Government to spread its help more widely? The official reports show various views on these questions. Thus, the Sixth Report of the Advisory Council on Scientific Policy (Cmd. 8874, 1952) considered the possibility of 'establishing in Departments concerned with private civilian industry, specialist technical and scientific organisations . . . with the broad function of revitalising industries which are technically backward'. This would be done by using research and development contracts. The Council did not pursue the idea, 'partly because of its potential expense', and partly because they thought that the function could be carried out by Research Associations with help from the National Research Development Corporation. At this stage the Council evidently contemplated concentration at *some* weak points; but in their Tenth Report (Cmd. 278, 1957) the idea of help widely spread seems to be implied. The Council thought it necessary to ask 'whether the national effort in research and development is properly distributed in relation to our needs', but found it 'impossible to express any detailed opinions about research in specific fields, or about the balance of the research effort between the main fields of work. The Royal Society in the field of pure scientific research, and the Research Councils in their respective spheres, regard it as their function to ensure that gaps in research are detected and if possible filled, where this is desirable in the national interest.' Some doubt may be felt about the ability of the Royal Society and the Research Councils to perform this function, in the absence of any proper way of assessing the facts; and the statement is redeemed

from implying an impossible policy of trying to fill *all* gaps in research only by the convenient phrase 'where this is desirable in the national interest'. It is interesting to note that the new Council for Scientific and Industrial Research, in its first report (Cmd. 428, 1958) asks '. . . how should resources be allocated to avoid spreading them over too wide a field?', and the Council's first actions suggest that it has this problem of priorities very much in mind.

The right policy will emerge only when the hard work of fact-finding and assessment has been done; but our studies suggest a few principles. The policy of 'reinforcing success', helping industries which are already showing signs of lively innovation to advance still faster, and thus to reach a commanding position, certainly deserves examination. It is probably, however, a rule for occasional rather than general use; its effectiveness is limited, simply because there is a limit to the speed at which human organizations can change. The policy of concentration at weak points, on the other hand, can be supported from our previous studies. We concluded in *Industry and Technical Progress* that technical backwardness is self-perpetuating; the backward firm or industry is caught in a situation from which it is very hard to escape. The industry is not attractive to men of ability, and therefore a forward-looking individual has an uphill task in recruiting the staff to support his efforts. Frequently there is a long record of instability or of low profits, and it may thus be difficult to finance new ventures either from reserves or from new capital subscribed by the public. The organization of the industry, even though it may be appropriate enough for the continued application of traditional methods, may be resistant to the application of new ideas, perhaps simply because the firms are too small to command staff which can understand, analyse, and apply them. The tradition of research may be weak or non-existent; if there is a Research Association it may be actively used by only a part of the industry; systems of management and relations with customers may be difficult to adapt to a situation of rapid technical change.

All this is in sharp contrast to the state of the technically progressive firm in a modern and advancing industry. Such a firm, we have found, is commonly of good 'general quality'; it is, for instance, progressive in management techniques, it recruits men

of high ability (who are attracted by the nature of the firm and of the industry), it is effectively organized to produce change and assimilate its effects. Unless circumstances beyond the firm's control become unfavourable, it can be relied on to continue its technical progress, and for this it will not require any special outside aid. Such firms and industries are the places where technical change is most likely, but not necessarily where it is most needed. It would therefore seem to be an appropriate general principle for the Government to concentrate its effort on some of the industries or firms which are least able to help themselves.

The policy of concentrating help on *certain* industries which are caught in the net of their own backwardness must, however, be sharply distinguished from a policy of aiding weakness wherever it may be found. There are some industries and firms which cannot be helped by any conceivable technical change; they are left stranded by changes in demand, or by the emergence of new products or new and protected suppliers. They are doomed as the stage-coach was doomed by the coming of the railways, and the proper object of policy is to secure their rapid and orderly contraction or disappearance, so far as is consistent with a fair and humane treatment of the workers and the districts concerned. The concentration of aid for technical progress should be on those industries which have great promise of change or development, but which are (for some reason) too weak to take the first steps by the power of unassisted private enterprise.

To a small extent, such a concentration already exists, both in technical education and in research; strong and progressive industries carry a large part of the burden of training, research, and development, while weaker industries leave more to State initiative. But the pattern is not at all clear, as we shall suggest on p. 114. Furthermore, it has been suggested to us that the principle of concentration should be carried a great deal further, and that massive Government resources should be concentrated on achieving a 'technical break-through', a swift change in technical possibilities, in certain trades which are exceedingly unlikely to command the resources to do this for themselves. Such a strategy would certainly be appropriate to the problem of self-perpetuating backwardness which we have

described; it is almost implied by the last sentence of our report, *Industry and Technical Progress* (p. 192): 'It will take much ingenuity by industry and government to break up the crust of habit and to divert lively and able minds from the places where change is most likely to those where it is most needed.'

Such a policy would not be easy to apply. An 'industry' is by no means as clear-cut a concept as the frequent use of the word might imply, and it would not be easy to identify groups of firms, incapable of sufficient self-help, whose techniques might be ready for change. It is not enough to see a technical problem whose solution would be valuable—such problems are innumerable; one would have to select problems whose solutions were sufficiently 'within sight' to give a definite promise of results from concentrated effort. There would have to be reason to expect that the solutions would turn out to be economically worth-while; and one would naturally require to see also some reason why the addition of Government resources should bring results not otherwise attainable by industry.

These three conditions were all satisfied in the development of atomic energy for peaceful purposes—a big problem with a solution 'in sight', a strong prospect that the solution would be profitable, and a virtual certainty that the task of reaching it was beyond the strength of private industry. This notable example encourages the belief that there may be others—perhaps the development of a new steel process (for there has been little major change in steel manufacture for many years); perhaps some major innovation in textile spinning, or in the propulsion of ships. Clearly an attempt to achieve such things would be exceedingly risky, and would therefore not be in the usual pattern of Government peace-time activity. Doubts might well be felt about the ability of Government departments to discern the right problems to attack. Yet it is not a sufficient answer to quote the flexibility and the other advantages of private enterprise, for we are by definition discussing problems which private enterprise is unlikely to be able to solve, and on which Government initiative seems appropriate. If therefore the process of fact-finding and assessment (which we consider to be so much needed) throws up opportunities for assisting a major technical 'break-through', we hope that the necessary concentration of Government aid will speedily be made.

CHAPTER 10

Government Aid for Research and Development

On 28 July 1915 the Advisory Council for Scientific and Industrial Research was appointed by Order in Council, and the corresponding Department (D.S.I.R.) was created a year later. Thus the chief organization by which the Government aids scientific research for industry was the child of war; but though created because of the weaknesses revealed by war, its purposes were essentially those of peace, and defence research has from time to time required separate organization. In 1915 there already existed the National Physical Laboratory, founded in 1900 with a small Government grant, and Imperial College, established in 1907 with a basis provided by the Royal College of Science and the Royal School of Mines. The new Advisory Council was instructed to keep in touch with the Government departments, and with the National Physical Laboratory, the Royal Society, and the universities and technical institutions; and it was to use all possible means 'to enlist the interest and secure the co-operation of persons directly engaged in trade and industry' (Cd. 8005, 1915.)

There appeared at the time to be a growing interest in co-operative industrial research, and D.S.I.R. at first conceived its function to be the giving of initial assistance to a movement which would shortly become self-supporting. In December 1916 Parliament voted £1 million (soon to be called the 'Million Fund') to be spent by an Imperial Trust for Scientific and Industrial Research. By 1920 twenty-three Research Associations had been founded, and these initially received a '£ for £' grant for five years. Great care was taken to avoid unnecessary Government interference; a White Paper published in 1917 (Cd. 8718) said 'if the help is to be effective, it must increase the British Manufacturer's independence and initiative. It must

avoid chaining him to the routine of Government administration, however efficient.' The D.S.I.R. report for 1919 stated that 'it would be fatal to the success of a Department entrusted with the encouragement and organization of research to concern itself with the exploitation or commercial development, or administrative application of the results which may be obtained'.

It shortly became apparent that the willingness of industry to support co-operative research was not sufficient to make the Research Associations viable; and the lack of provision for capital needs was a serious handicap. One Research Association announced in 1923 that it could do without Government grant, but otherwise the Associations were hungry for more money, and it was agreed that a further five years of grants on a diminishing basis might be obtained (D.S.I.R. report, 1923). In general, the grant in the first year would be 50 per cent. of the minimum income without which effective results could not be obtained, conditional on industry raising the other 50 per cent.; and the grant would decrease by a fifth of its original size each year. But it was recognized that some Associations, for instance the British Scientific Instrument Research Association, served many trades but could expect direct support from only a few firms, and a more generous grant basis was provided for these.

Under the diminishing-grant scheme, Government aid was halved between 1923 and 1929, but income from industry rose very little. A scheme limited to a proportion of the total income of the Association operated for a time in the 1930s, and was then replaced by the present method of finance, by which an Association receives a 'block grant' (negotiated for a five-year period) conditional on raising a stated minimum sum from its members, and an additional grant which, within a precribed upper limit, is proportional to the excess of industrial contributions over the minimum sum. Thus members know that they *must* raise a definite amount, or the Association will lose its grant; beyond this, expansion is encouraged by the supplementation of extra money raised.

The broad effect of this is that the Government has become a 25 per cent. partner in the finance of co-operative industrial research, and the total income of the Associations was by 1957–58 twenty-five times larger than in the mid 1930s—or (say)

eight times larger in real terms. The total income of forty-six recognised co-operative research organizations was in 1957–58 £7 million. But, striking as the growth has been, it is only a small part of the total research effort of the country—about a sixtieth of total research and development expenditure, and less than a thirtieth of the research and development expenditure of private industry.[1]

A further £4 million was spent by D.S.I.R. in 1957–58 on the support of its own research stations. These include the National Physical Laboratory (transferred from the Royal Society in 1918), the Geological Survey and Museum (transferred from the Board of Education in 1919), and a mixed bag of research stations dealing with (e.g.) water pollution, road problems, mechanical engineering, hydraulics, radio, and building work. Their function is to maintain scientific standards, to serve as independent testing centres, to make surveys of natural resources, and to undertake industrial investigations of national importance which cannot be assigned to one industry, and which it is felt would not otherwise be covered adequately. They also undertake research which aids the functions of Government; for instance, road research, since roads are maintained by public authorities. Each of the research stations was established in the first place for good reasons, 'in the national interest'; but the justification for their special position as State-financed institutions may alter, especially if some of their work is, or can be, duplicated in ordinary industrial research laboratories. The first report (Cmd. 428, 1958) of the (executive) Council for Scientific and Industrial Research, which succeeded the Advisory Council on 7 November 1956, showed that changes were being brought about in the functions of the research stations.

Finally, D.S.I.R. has important functions which lie substantially in the field of basic research—the support of postgraduate training by grants to individual students, and the support of special research projects by investigators of acknowledged standing, notably in the Universities. The expensive items in the grants for special researches have recently been in the fields of nuclear physics and radio astronomy, and are

[1] See Cmd. 278 (1957), p. 2. Two-thirds of the research and development expenditure in private industry was in 1955–56 financed by Government, mostly for defence purposes.

some way from any point of industrial application; but some of the smaller grants appear from their description to relate to work whose support is no doubt fully justified, but which might in other circumstances have been done in an industrial laboratory. Examples are: 'A study of the production and properties of rolled metal foil'; 'Study of high temperature creep'; 'Optical studies on the behaviour of diamond machine cutting tools'; 'Sheet pile walls in clay'; 'Behaviour of piles and pile groups in sand'; 'The assessment of noise in coal mines' (D.S.I.R. 1956–57 report).

The Research Council of D.S.I.R. is one of four which are responsible to the Lord President,[1] the others being the Agricultural Research Council, the Medical Research Council, and the Nature Conservancy. The Agricultural Research Council dates from 1931. Its functions were until recently to co-ordinate the agricultural research work financed by the State (notably that of the Ministry of Agriculture and the Department of Agriculture for Scotland); to advise the agricultural Departments on scientific matters and on the grants-in-aid which they make to research institutes; to use its own grant-in-aid to support research essential to the co-ordinated programme and not covered by the institutes financed by the Departments; and to finance post-graduate work and special research in much the same way as D.S.I.R. does. Since 1956 the Council has itself been responsible for state aid to research institutes in England and Wales, but not in Scotland. There are twenty-three grant-aided independent research institutes in Great Britain, and eighteen institutes and units directly under the Research Council. Although private initiative in agricultural research has a long history, a notable landmark being the foundation (in 1843) and endowment of Rothamsted Experimental Station by Sir John Lawes, the present position is that only a very small part of agricultural research is financed from private sources. The main part of the work supported by the Agricultural Research Council, at a cost now about £4 million a year, is in this way comparable to that of the research institutes directly supported by D.S.I.R., though the A.R.C. makes greater use of university staff to direct its smaller units.

[1] Or, more accurately, to Committees of the Privy Council, of which the Lord President is chairman.

The Medical Research Council carries still further the policy of supporting the promising work of individuals, many of them in universities. About 20 per cent. of its budget (of about £3 million a year) is spent on the National Institute for Medical Research; most of the rest goes to some seventy research units and in temporary research grants. The Council dates from 1920, though a Medical Research Committee was set up in 1913 under a provision of the National Health Act of 1911. For our present purposes, it is relevant to note that the Council supports work on industrial fatigue and on various aspects of working conditions, and on the prevention of accidents. It also undertakes other work of a direct industrial interest; for instance, it is supporting with money received from the tobacco manufacturers work on the causes and prevention of lung cancer.

Important as the work of the Research Councils is, it must be kept in perspective. We have already pointed out that the expenditure of Research Associations is small compared with the research and development expenditure of private industry. Figures for the year 1955–56 published by D.S.I.R.[1] show that three-quarters of the national research and development effort was paid for by Government, and 60 per cent. of the whole was for defence purposes. This dominance of defence research is very significant, though much of it, of course, yields 'civil benefit'—for instance, improvements to aircraft, which can be put to general use. The sources of funds for research and development other than for defence can be analysed roughly as follows:

	1955–56 £ million	1955–56 Percentage
Government civil departments (including civil work of Atomic Energy Authority, and university grants)	34·5	28
Research Councils	12·0	10
Private and nationalized industry	72·3	59
Other (university endowments, foundations, &c.) .	3·7	3
	122·5	100

Of the £34·5 million spent by Government, other than through the Research Councils, about £10 million was for the universities, and it is possible to deduce that much the largest element in the remainder must have been spending by the Atomic

[1] *Estimates of Resources Devoted to Scientific and Engineering Research and Development in British Manufacturing Industry, 1955*, H.M.S.O., 1958.

Energy Authority, though the Colonial Office, the Ministry of Transport, and the Post Office are also substantial spenders on research.

Development (and to a limited extent research or design) is also financed by the National Research Development Corporation, whose main work is to hold the patents for inventions made in Government establishments and to secure (if necessary by financial backing) the further development and exploitation both of these inventions and of those which it considers worth accepting from private sources. The Advisory Council on Scientific Policy drew attention in 1953 to the fact that N.R.D.C. had no power to initiate research 'or to perform the vital function of identifying new needs'; by the Development of Inventions Act, 1954, the powers of the Corporation were therefore extended, and it is allowed (subject to the approval of the Lord President) to initiate research likely to lead to new inventions. This is potentially of considerable importance, but, although N.R.D.C. has been concerned with important fields of development, such as electronic computers, its annual expenditure on development contracts amounts to little more than £250,000. It is an important intermediary, but not so far a significant source of finance.

To sum up—the greater part of the research and development effort supported by the Government is incidental to defence. Of the remainder, most is financed through a group of institutions for which the Lord President of the Council has to answer—the Research Councils and the Atomic Energy Authority—and the Lord President has the Advisory Council on Scientific Policy to assist him. Another substantial share is financed by the Treasury through the University Grants Committee; the rest is found by a variety of Departments and State-sponsored bodies, among which the National Research Development Corporation could have a key position.

What evidence have we of the adequacy or suitability of this complex apparatus for providing Government aid to research and development? In considering this, we have supplemented our earlier studies by further interviews and inquiries about the Research Associations and the Government research stations, and we gratefully acknowledge the help which we have universally received.

One problem which besets any attempt to give Government aid to technical progress is that a firm cannot be helped unless it knows it needs help, and it cannot be helped unless it is capable of receiving and understanding what is offered. A firm which is wholly 'parochial', self-complacent, or traditional is not likely to turn to a Research Association or a Government laboratory for help. A firm which does not employ scientists and technologists may not have anyone capable of appreciating the significance of a technical bulletin from its Research Association. It is thus generally found—and we would confirm this from our experience—that it is the larger and livelier firms, and frequently those which have research departments of their own, which make the fullest and most effective use of co-operative and other State-aided research institutions.

It must be remembered also that since the First World War there has been a great increase in the provision within individual firms for research, and that co-operative facilities which were originally encouraged as a way of bringing scientific thought to bear upon traditional processes may now have to seek a different justification. The change in the nature of the problem is not, we think, easily reflected in a change in the pattern of Government support; a grant once given cannot readily be withdrawn. Some industries finance nearly all their own research; others, of a similar character, place the whole burden on the Government. We find no evidence of Government support for research on oil refining, drink, or tobacco, and the help given to the motor-vehicle trades must be very small; on the other hand, the shipbuilding and marine-engineering industries rely on Research Associations and Government laboratories for over 80 per cent. of their research, and the building trade gets most of its research directly financed by Government. The radio trade spends quite a lot on research, but gets little Government help, although it is a trade containing many small firms. Every one of these facts can, we are sure, be justified from the nature and history of the trade and the problems of research in times past; we doubt if they can all be justified from current circumstances alone. Why, for instance, should not a greater share of building research be financed by the large contractors?

We raise this point because it is relevant to the principle of concentration which we have mentioned in the last chapter.

The traditional reason for Government aid to research and development is to enable industry to achieve something which, by reason of its structure and resources, it cannot do for himself. If this reason is accepted, then it is natural for the pattern of research aid to change, the advance of one industry freeing resources which can be concentrated on the needs of another. But in fact three other reasons for Government aid seem to have entered into current thinking. One is to regard it as a subsidy to research, analogous to the subsidy implicit in the tax treatment of research expenditure; it is a means of making research cheaper than it would otherwise be, and thus of persuading industry to use it more fully. Another view is to regard Government aid as a means of financing basic research which (for various reasons) is not being done in the universities, and which is too far from the point of application to engage the enthusiasm of industry. A third view is to regard research and development as a candidate for nationalization, an activity which should naturally be undertaken by the community as a whole and not for the exclusive profit (or loss) of individual firms.

The last attitude raises questions of political philosophy which we do not here discuss. The 'subsidy' argument is not in itself sufficient to justify direct Government grants to research stations; the same pressure to undertake research can be exerted (and is in fact exerted to a much larger extent) by special tax treatment for research expenditure. The 'basic research' argument has more validity, for it can be suggested that, whereas a modern science-based industry can be parasitic on university research (which is predominantly Government-financed), many older industries get little university help in research. Thus direct Government aid for research and development can be regarded as a means of redressing the balance—and, on this argument, the aid should be concentrated on industries without a strong scientific foundation. This might in practice produce results not much different from those to be expected from a reliance on the traditional argument for helping those too weak to help themselves; though the traditional argument could be used to justify a general aid to small firms and small farmers, as well as special aid directed to industries which lack a scientific basis.

We have made extensive inquiries about the liaison activities

of the Research Associations. It is clear that most Directors of the associations attach considerable importance to this work, though some still think of it as a regrettable necessity, diverting funds from 'real' scientific work. Some Directors complain of the difficulty of retaining good men if they are expected to spend part of their time on what they regard as 'mere salesmanship'. The need for personal contact through travelling liaison officers, conferences, and courses, and for contact 'on the shop floor' rather than high up in the firm, is generally stressed.

There is, however, a distinction, which is not always clearly made, between two kinds of liaison service to be provided by a research organization. One kind starts from the current work of the organization, and conceives of liaison as 'selling' the latest research results to the industry. The other starts from the needs of the firms in the industry, and helps them to find the knowledge which they require, even though it may have little relation to the current research programme. The first is salesmanship of the research output; the second a general advisory service, a form of education which takes account of the latest technical knowledge, but which may need to reach back into quite elementary matters. Both can, of course, help to keep the research organization in touch with the needs of the industry which it serves.

An example of work which is primarily educational is the National Agricultural Advisory Service; another is the widespread advisory service of the Ministry of Works, which includes the publication of simplified leaflets on aspects of good building practice. Most Research Associations provide some elements of an educational service—they are willing to answer queries from their members, they offer library facilities, they publish simplified papers (such as *Knit-Knacks*, for the hosiery trade). But the emphasis is naturally largely on the communication of the current results of research; a Research Association budget does not often run to the provision of a national and comprehensive advisory service.

We therefore suggest that State aid should be separately assessed [1] in two classes, advisory aid and research aid. In an in-

[1] Separate *assessment* does not mean separate *organization*; it is often desirable to keep the research and advisory services closely related, and perhaps using the same personnel.

dustry whose smaller units tend to be ignorant of the best modern practice, advisory aid would be considerable, and would make use of the best techniques of propaganda. In an industry which is considered ripe for an advance in technique, or for the difficult transition from a craft to a scientific basis, but which (by reason of its structure) cannot support enough research of its own, research aid would be considerable. Owing to the need to avoid discontinuity in present work, we envisage the immediate effect of such a policy as being the supplementation of research funds by money earmarked for advisory or education services; the provision of these services for small firms seems to us distinctly a service to be undertaken by the State. In the long run it may even be that the State expenditure on research aid for some trades, which now have a vigorous research tradition, should be reduced, in order that a greater effort may be concentrated on others.

A special problem which has been brought to our attention is that of sponsored research. It is suggested to us that, though members of a Research Association may be willing to ask for help in minor matters of 'trouble-shooting', they do not like to put up major proposals whose benefit (if research is successful) will accrue to their competitors as well as to themselves. Alternatively, it is suggested that if a firm has a major problem which is peculiar to its product or its method of manufacture, the Association will not be willing to give it high priority, since the benefit will not be widely spread.

In fact, most Associations have carried out some sponsored or confidential research for their members at some time in their existence, charging for it at cost price or by means of a specially increased subscription rate. Some Directors do not like it, since it cuts across the research programme designed for the benefit of all members; others feel that it is a way of improving industrial support, and should therefore be tolerated. There now exist in Britain at least five commercial institutes for sponsored research, though they are on a small scale. It could be argued, therefore, that if the need for sponsored research is really acute, it will be met either through the Research Associations or through the commercial bodies. This is perhaps a little optimistic. The United States sponsored research institutes perform a valuable service by going out to firms and selling the idea of

research as a good business proposition. The existence of State-subsidized Research Associations in Britain limits the growth of unsubsidized commercial institutes, but the Research Associations are themselves much weaker in 'selling' their services to individual firms. The situation demands in fact that sponsored research should not merely be tolerated, but should be actively expanded by offers of research and development services to help individual firms to overcome difficulties or reduce costs.

Another aspect of the adequacy of State aid is the provision for development work. 'Development' may roughly be defined to begin when decisions to try to proceed to full-scale production have been taken, and it is frequently a much more expensive stage than laboratory research. We drew attention in *Industry and Technical Progress* (p. 71) to the possibility that a Research Association, concentrating on much-needed basic research, might simply create a 'development gap'; and we mentioned the action of the Shirley Institute in setting up a separate organization to deal with the difficulties of the development stage.

We find on further inquiry that, out of 41 Research Associations and Councils giving us information (the total number of D.S.I.R. grant-aided co-operative research organizations was at the time 46)—

- 35 had undertaken work at pilot-plant level, either in their own laboratories or in a member's factory;
- 29 had constructed equipment for members (it must be remembered that much R.A. work is concerned with instrumentation);
- 14 had found difficulty in getting inventions taken up and developed by outside firms;
- 7 already had a development section;
- 7 more considered that there might be need for such a section.

These figures are not particularly revealing, because Research Associations are a very mixed lot—some dealing with products, some with processes, and some with the properties and uses of a particular material, some with one trade and some with many. Thus a full-scale experiment or 'pilot plant' in shipbuilding requires a whole ship, which is most unlikely to be built purely for

research purposes; a full-scale experiment in the scientific-instrument trade is the natural way of proceeding. Nevertheless, it was the British Scientific Instrument Research Association which pointed out to us that too much 'production scale' work might mean duplication of effort; almost every firm will have to do some additional work to adapt the invention to their production methods. The Association might develop an instrument using sand castings, only to find that the manufacturer had to re-design it to use die castings.

In fact, the point to which development work should be pushed—that is, the point at which industry can and will take over, without undue duplication of effort—will vary from trade to trade. One informant suggested to us that a Research Association will sometimes hold on to an invention, seeking 100 per cent. perfection, when 70–80 per cent. perfection would be welcomed by industry and might save thousands of pounds a year. Another, in a closely related trade, told us of the danger of giving an invention to the trade in a 'half-baked' state, so that it fails in the final stages of development. We consider, however, that in some trades there is need for more development work than is at present carried out by the Research Associations or Government laboratories. This need usually arises because the firms which could appropriately develop the results of research are backward, conservative, and unreasonably unwilling to risk changes in markets and a loss of goodwill for existing products.

We must emphasize that this trouble is occasional rather than general. Many Research Associations claim to have no difficulty. 'Give the machine makers the right instrument and they will take it up and risk a loss on it'; '. . . (the industry) presents a vast number of problems which are urgently in need of a solution, and when a solution is finally obtained application is consequently not difficult'. Some Associations, however, make the important point that resistance to innovation is easily overcome if a complete machine can be demonstrated, working in a profitable manner; but it can be considerable if the innovation is put up to the industry in an incomplete form, or as a modification of existing plant, so that its commercial possibilities are not easily appreciated.

The function of a development section is therefore to carry an

invention through the stages of adaptation to commercial use (for instance, by placing development contracts) until it reaches a stage of perfection at which it appeals to potential users and is regarded by its manufacturers as a sound commercial proposition; or (of course) until it becomes obvious that it must be rejected as having no commercial future. A number of the Research Associations which have 'development sections' do not mean quite this; they have simply set up a patent-holding subsidiary whose function is the commercial *promotion* of inventions, rather than 'development' in the strict sense. This is a useful function, and it is often desirable to relieve the Director of Research of responsibility for it, putting it on to a management experienced in commercial matters; but there is in addition the occasional need for true development. One Association in a large modern industry comments:

'When we invent or develop instruments for the use of our members, we find that instrument-making members are reluctant to undertake any development work at all, so that to secure manufacture we have to engineer a commercially saleable article. We have felt that there is a case for a development section to undertake work of this type, so that we could recover from sales the expenditure in development.'

(The last sentence apparently means that more development work could be done if its cost could be partly recouped.) Two more Associations would like to have a development section, but see no prospect of financing it.

There should, in fact, be no great difficulty in dealing with this problem. The better-established Research Associations should set up Development Companies and place contracts for the development of their inventions. Those which lack the strength or experience to do this can (together with the Government laboratories) have access to the experience and the funds of the National Research Development Corporation. Some such policy was suggested in the Sixth Report of the Advisory Council on Scientific Policy, but little progress has been made. It is possible that the structure, terms of reference or policy of N.R.D.C. might need some change; and it may be worth considering whether a greater unity of approach to development would not be achieved if responsibility for N.R.D.C. lay with

the Lord President's office rather than with the Board of Trade. Such a change could easily fit in with the suggestions sometimes made for having parallel and associated Research Councils for fundamental science and for technology and development, these being activities requiring different skills in their direction and assessment.

It appears to us, however, that since existing facilities for the finance of development through N.R.D.C. are not fully used, Government support may need to go beyond the financing of development contracts. We are impressed by the value of N.R.D.C.'s support for the development of electronic computers, which rested on a judgement that 'these things will be really important in ten years' time'; but other inventions of similar long-term value might not be so readily developed within private industry. When necessary, therefore, we think that State development companies should be created, charged with the management as well as the finance of the process of development.

In summary, what we would like to see is a re-assessment of Government aid to research and development, designed to make it more likely that (while continuing to serve the special needs of Government) it will give help to industry at the points where in the long run help is most needed. This re-assessment would require separate consideration of the needs for advice, for research aid, and for development aid. Every effort should, we think, be used to make N.R.D.C., perhaps supplemented by special development companies, into an effective instrument of development on behalf of all Government-aided research bodies which cannot achieve fully adequate development from their own resources. The powers of N.R.D.C. to stimulate research (as well as development) should be used with vigour to fill in gaps which may appear in the structure of industrial research, or to recommend to the Research Councils action for filling them. This seems to us to be a function which is appropriately carried by a body directly in touch with the economic, as well as the technical, problems of industry; and indeed the whole process of assessment of Government aid needs to be considered as a problem in the joint use of economics and technology.

CHAPTER 11

Some Aspects of Educational Policy

OUR earlier studies, made during a time of rapid industrial expansion, naturally confirmed the existence of a strong and rising demand for scientists, technologists, and technicians.[1] We pointed out that the crucial shortages (that is to say, those which were the sole reason holding up development) were to be found especially among engineers, designers, and draughtsmen, and in certain special fields such as chemical engineering and metallurgy. The degree of shortage varied with the attractiveness of the industry or firm, and we pointed out that some industries and firms were critically short of competent and well-trained managers. We thought that, except perhaps at the highest levels of ability, the numbers of intelligent children were adequate to sustain a much larger output of scientists, technologists, technicians, and managers; and we were therefore led to inquire into the possibility of wastage or misdirection in the educational system. We considered that wastage in the school years was substantial and in part avoidable, and that it took the form both of failure to develop a child's talents and of misdirection to careers in which those talents have insufficient scope. The shortage of science teachers was, and remains, crucial, and the methods used to alleviate it appeared to us inadequate. In higher education we drew attention to the limits to university expansion set by the maintenance of the customary standards of entry, and to the very heavy burden thus placed on the technical colleges.

The demands of a scientific industry upon the educational system have been the subject of prolonged debate and controversy during the past decade—not least at the meetings of one of our sponsoring bodies, the British Association. There is no point in pursuing arguments which are growing stale by repetition. We have, however, reviewed the whole matter again, ob-

[1] See *Industry and Technical Progress*, chapter 9.

taining considerable fresh evidence, in order to see if there were aspects which were receiving insufficient attention, or changes in the situation which ought to be noted. This chapter has the limited purpose of trying to add something new to the public discussion; it would be quite impossible to be comprehensive in writing on so vast a subject.

There has in recent years been a considerable growth in the proportion of children taking science subjects at schools, and therefore in the potential output of scientists and technologists. Side by side with this, there was in the years 1957 and 1958 a slackening of the demand for certain types of trained personnel, associated with the declines in industrial production of those years. This has led people to ask if too much emphasis has been given to the production of more scientists, and in particular to question the estimate published by the Ministry of Labour and the Advisory Council on Scientific Policy,[1] that a 60 per cent. increase in the number of qualified scientists and engineers would be needed over the decade 1956–66.

The assertion that greatly increased numbers of scientists and technologists will shortly be needed rests on twin foundations: first, that there has been a high rate of expansion of the scientific content of industry, and of its output (if the four years 1956–59 are ignored), that this is likely to continue, and that it will involve an increased use of scientifically trained staff; and second, that comparisons with some of Britain's industrial rivals (and in particular with Russia) suggest that they are ahead of us, especially in the relative numbers of qualified engineers.[2] The second foundation is weaker than the first—it is possible, for instance, that Russia is wasteful in her use of engineers—but together they certainly provide a reasonable support for a belief in a considerable long-run increase in the demand for scientists and technologists. They do not, however, provide any sound means of judging the speed of that increase, and it is not clear that the assumption made in *Scientific and Engineering Manpower in Great Britain*, that the employment of scientists must increase *pro rata*

[1] *Scientific and Engineering Manpower in Great Britain*, H.M.S.O., 1956.

[2] In 1956 Britain had about 10 qualified scientists and manufacturing (including Higher National Certificate holders) per thousand employees in engineering, construction, mining, and transport, the United States had about 21, and Russia about 18. The British output of qualified scientists and engineers was under 4 per year per 10,000 population, the Russian over 8.

with industrial production, is necessarily correct. It may be either too high or too low—though it is worth remembering that the disadvantages of having too few scientists are much greater than the disadvantages of having too many. There is in our present state of knowledge some danger in confining the discussion within the narrow bounds of a statistical approach; and we try to examine the problem in a broader way later in this chapter.

Before doing so, however, there is one inference from the statistics which seems to us to deserve more attention; namely, that the shortage of technicians is in certain lines more serious than that of scientists and technologists, and that the output of technicians is liable to become progressively less adequate. For this purpose a 'technician' is conveniently defined as a person who has reached a standard such as the Ordinary National Certificate (or the City and Guilds Full Technological Certificate); some firms (e.g., in the electrical industry) would include all Higher National Certificate holders, if they do not go on to obtain further qualifications, while others are disposed to regard some of these as technologists. The line between 'technician' and 'technologist' is an arbitrary one, and it is natural that there should be some staff who can plausibly be assigned to either class.

It is asserted in the 1956 White Paper on Technical Education [1] that 'as many as five or six technicians may be required to every technologist'. We have made inquiries from the largest firms in British manufacturing industry, chosen from a list arranged in order of size as defined by net tangible assets, asking for the ratios of technologists, technicians, and craftsmen which they regard as normal in their recruitment policy. Forty-seven firms replied (out of sixty-four approached), and in addition one giant firm gave us separate replies for its fourteen divisions. The ratio which emerges is very different from that in the White Paper, being approximately one technologist to two technicians.[2] But the best estimates we have been able to make of the *output* of these two classes suggests that, after allowing for those who go on to obtain higher qualifications, very few more

[1] Cmd. 9703, p. 19.

[2] In research and development the ratio of fully qualified scientists and engineers to *all* other staff is 1 to 2·3 (manufacturing industry excluding aircraft): *Estimates of Resources Devoted to Scientific and Engineering Research and Development in British Manufacturing Industry, 1955*, H.M.S.O., 1958.

technicians are becoming available to industry than technologists: the ratio is probably nearer to 1 to 1 than it is to 1 to 2, let alone 1 to 5 or 6. Although our information is confined to large firms, we think that it is *prima facie* evidence of a shortage. This is confirmed by some of our case studies, and also appears in some of the comments received from the large firms, such as: 'It must also not be overlooked that many technologists, because of the shortage of technicians, are spending time on work which more properly comes within the technician category, and if there were more technicians the technologists could be more effectively employed.'

This is a situation liable to become worse. Public interest has been centred on the output of scientists, and the developments in technical education have been strongly biased towards 'higher technological studies'; it has been suggested to us that in some places this has led to a neglect, or at least to a *relative* neglect, of Ordinary National Certificate work. The trend towards later school leaving must tend to divert from craft apprenticeship able boys who might have reached the technician class by part-time study and promotion, and it is not certain that they will be picked up at a later age. There is also a special difficulty which affects the next few years. The number of young people reaching the age of 15 is expected to rise by 1962 to a level more than 50 per cent. higher than in 1956. Provision, inadequate but still very considerable, is being made, in universities and colleges of advanced technology, for those able to obtain professional qualifications through higher education. It is still much less certain how far industry will be able to respond to the pleas of the Carr Committee for an increase in the intake of apprentices; the response is at least likely to be patchy. It is therefore possible that, unless corrective measures are taken, there will be in the mid-1960s a swift rise in the numbers of scientists and technologists entering the labour market, not matched by an equivalent rise in the number of technicians, and that any existing lack of balance will be made worse.

In the public discussion about 'the shortage of scientists', a number of quite different issues have become confused; and we therefore think it desirable to separate out five different questions, so that we may consider whether our evidence entitles us to offer any answers to them. The five questions are:

(i) Is industry getting its fair share of first-rate men?

(ii) Is education in Britain terminated, for most children, at too low a level?

(iii) Is the scientific content of the education of the ordinary citizen sufficiently great?

(iv) Are there appropriate and adequate vocational training facilities for—

(*a*) craftsmen,
(*b*) technicians,
(*c*) technologists, and
(*d*) managers,

and do enough people take advantage of them?

(v) Do the right people take advantage of them, or is selection for vocational training poor and wasteful?

It is quite clear from our conversations with industrialists that part of the sense of a 'shortage of scientists' is a shortage of really first-rate men for research, and that this is equally felt as a shortage of first-rate managers and administrators. But 'first-rate men', however their qualities are defined, are in exceedingly short supply; there will never be enough of them, and the question is therefore as we have stated it—Is industry getting its fair share? There can be no precise answer to this, but some pointers can be given. First, inquiries have failed to reveal any substantial trade or profession which is not acutely conscious of the lack of first-rate men. It has been suggested to us that in times past the Civil Service could take the cream of the nation's talent, but this is not what is felt by the Civil Service Commissioners today. Second, the attraction of industry has certainly denuded the school-teaching profession of good scientists and mathematicians, and has thus threatened the future supply of scientists. Indeed, it would be expected that, in so far as people choose their employment so as to get the greatest salary, private industrial firms would be better placed than most other employers to out-bid their rivals. We conclude that we see no evidence that industry in general is failing to get its fair share of first-rate men (though particular industries, which for some reason are unattractive, may be short); some part of the complaints about the shortage of scientists may therefore be in reality a complaint against Fate or the laws of genetics.

Next we inquire whether a present or future 'shortage of scientists' may be due to the characteristic of the British educational system, that so large a proportion of the population terminate their education at the minimum school-leaving age of 15. This problem can be argued in terms of the proportion going to grammar schools (since these are the children most likely to continue education to a later age), or in terms of the right school leaving age, or in terms of the intensity of effort to give further education through day-release classes and sandwich courses. It is certainly true that both the United States and Russia have a higher proportion of children in full-time education beyond the age of 15, and it can be argued that this is a necessary foundation for modern scientific industry. (The argument from example is, however, weakened by the low quality of much United States education, and by the fact that the latest Russian reforms favour part-time rather than full-time education.) We offer no evidence on this matter of the period of education, but it seems to us to need further study and research, which should examine the cost (including the shortening of working life) of additional years of education in relation to the benefits to be expected.

The content of science in the education of most citizens is small; this is true not only of those educated at secondary modern schools but also of those grammar- or public-school boys and girls who choose at an early age to specialize in arts subjects. There can be few people in positions of high responsibility in the United Kingdom who have not had to study the plays of Shakespeare; but there are no doubt many who could scarcely distinguish the law of Ohm from that of Boyle. This is partly the result of specialization, but the United States, though having a lesser degree of specialization, is also exceedingly weak in the scientific content of education; in contrast, Russia has an unspecialized system with a considerable content of science and technology. On this matter, we think that our evidence entitles us to say that the cause of technical progress would be favoured by a higher scientific content.[1] This is so for two reasons. First, as has been suggested in Chapter 3, the transmission of scientific

[1] It is our personal opinion that such a change is essential on general educational grounds, and not simply on the narrow considerations of economic benefit here discussed.

ideas (for instance, from a research laboratory to a Board of Directors) would be less impeded if there were a generally higher level of 'scientific literacy'. Non-scientist managers frequently, of course, attain an expert knowledge of the traditional techniques of their trade, but they may have great difficulty in understanding an incursion of ideas from some quite different scientific field. A great deal of effort is at present spent on overcoming the resistance to the communication of scientific ideas, and anything which would lessen that resistance is to be welcomed.

The second reason is that industry would be better able to meet demands, perhaps unexpected, for new kinds of technical skill if the reserve of people with some grounding of science were greater. A boy who will leave school in 1965 may still be at work in 2015; it is proper to have a certain humility about the ability to foresee the industrial demands even of the former year, let alone of the latter. Since only about a fortieth of the male labour force is 'turned over' by recruitment and retirement each year, it is clear that many demands for new types of skill are met by re-training the existing labour force; there is a presumption that skills requiring a background knowledge of science will become more common as the scientific content of industrial processes increases, and that industry will therefore be more flexible if more people have a grounding of science.

On the adequacy of vocational training facilities, and the demand to use them, our summary comments are as follows:

(a) *Craftsmen.* The immediate problem here is that considered by the Carr Committee,[1] namely the difficulty of expanding the intake of craft apprentices to provide training for the large generations of school leavers in the early 1960s. The problem here seems to us to be that many large firms are already doing more than their fair share of apprentice training, and are unlikely to feel that their interests demand that they should also provide for most of the excess of school-leavers. Many medium and small firms (and even a few large ones) are parasitic upon other firms for their supply of craftsmen; this is especially likely to occur if the firm is too small to have a proper system of apprentice training, or if its demand for craftsmen is away from its

[1] *Training for Skill*, H.M.S.O., 1957.

main industrial interest (e.g., maintenance men in a biscuit factory). There are some interesting schemes for the joint training of engineering apprentices by groups of firms, but these are few and have so far proved difficult to multiply. The prospect of persuading the larger 'parasites' to take their share of apprentice training is uncertain. It therefore appears likely that the training facilities for craftsmen will be inadequate, perhaps grossly inadequate, in the early 1960s, and that in consequence there will be an underprivileged generation of school-leavers condemned to unskilled status. It happens that the employment prospects of this generation will be made somewhat worse by the ending of National Service.[1]

(b) *Technicians.* We have already stated a provisional view, based on the statistics and on comments from industry, that the output of technicians is inadequate and may become more so. It must be remembered that technicians are also in critically short supply in universities, research institutes, and schools. The inadequate supply is not necessarily due to lack of facilities, for in some areas the technical colleges could take more candidates for Ordinary National Certificate work. But the quality of the facilities, in terms both of the help and encouragement given by the employer and of the staffing and equipment of the technical college, may not be good enough; this perhaps helps to explain the very high rates of wastage in the National Certificate courses. We referred in *Industry and Technical Progress* to the fact that we had found few firms which seemed to us to have given enough thought to overcoming the shortage of draughtsmen; we now think that the same criticism is valid for technicians in general—not enough ingenuity is being used to seek out promising candidates and to devise new ways of training them, though there are signs of change in a few places. We have, however, noted with interest a scheme of local-authority scholarships for technical training combined with industrial experience—a new kind of 'sandwich'—which offers a new way of reaching the technician class.

(c) *Scientists and Technologists.* Present plans for university expansion are believed to aim at providing for 136,000 students (of all subjects) in the mid-1960s (i.e., for about 35 per cent.

[1] For a good discussion of the problems of apprenticeship, see report of conference held on 9 July 1958, *Journal of the Royal Society of Arts*, No. 5027, October 1958

more than at the time of writing, the increase in scientific subjects being somewhat greater); but, because of the 'birth-rate bulge', it seems inevitable that a considerable number of potential university entrants must be disappointed in the period 1964–67. But there are also possibilities of expansion, of unknown size, in higher technological education outside the universities; the Colleges of Advanced Technology are getting established, the Diploma in Technology is coming into operation, and the system of technical education is flexible and varied in its opportunities. It is true that the rate of expansion in training facilities is not adequate to provide the numbers of scientists and engineers envisaged as needed in the report on *Scientific and Engineering Manpower in Great Britain*; but other obstacles to technical progress might have made it very difficult to absorb usefully an extra 60 per cent. of scientists and engineers in a decade. It is clear that there will at least be a very considerable increase in the numbers of scientists and technologists becoming available to industry, and that (because of the larger generations now reaching maturity) the limit up to about 1967 is likely to be set by training facilities; thereafter it might conceivably be set by the numbers willing to be trained.

(d) *Managers*. The question of training for management still gives rise to much controversy, between those who believe that practice is the only worth-while training and those who consider that practical training will be more effective and better directed if it is accompanied or preceded by a theoretical course. The advocates of 'practice only' have weakened to the extent of admitting that there are various management techniques (such as work study) which can be learnt, and courses on these techniques are now frequently found in technical colleges. Many other experiments in management training have been tried, in universities, technical colleges, firms, and professional bodies, but without yielding a generally acceptable pattern. We think it likely that technical progress is slowed down by a lack of good and lively managers, but whether this in turn is to be related to a shortage of management-training facilities is less certain; some would argue that the trouble is lack of appreciation of what management training can achieve. Clearly there is here a subject needing further research and consideration, and we have one suggestion about it to make below.

The question of whether selection for vocational training is adequate is related to such problems as the 'wastage' of potential scientists through early leaving from school. We have nothing to add to what has been written elsewhere on this subject.

What are the policy implications of the various points we have raised? In considering this, it should hardly be necessary to say that life is more than work, and that education is more than the provision of trained man-power for factories; and yet some of the public discussion seems to us to have accepted too easily the primacy of narrow vocational considerations in determining educational policy. Our few recommendations therefore carry an implied 'other things being equal'; we should like to see them applied in so far as they are not over-ridden by larger matters of educational policy.

1. There should be increased attention to the education of technicians. This involves an improvement in the scope, efficiency, and attractiveness of facilities in the technical colleges for Ordinary National Certificate work: continued pressure for a change of policy by those firms which do not provide day-release for apprentices: and a multiplication of the routes by which a man or woman may become a technician, special attention being given to recruitment from the grammar schools at 17 or 18. Action is needed (and, we think, needed urgently) by both industry and Government; on the Government side it will be necessary to find more money in order to improve the middle as well as the higher work of the technical colleges.

2. There should be a wider spreading of the burden of training craft and technician apprentices. Firms which avoid the need for training by attracting skilled men from other firms with high wages are failing in a national duty. We hope that there will be a rapid spread of joint schemes for the training of engineering apprentices by small firms; the Government could help all apprenticeship schemes by a tax remission proportional to the number of apprentices in training. (We are not here proposing that the total weight of company taxation should necessarily be reduced, but that it should rest more heavily on firms which have no apprentice training costs to meet.) Unless there is an early and full response to the pleas of the Carr Committee for an expansion in the intake of apprentices, other forms of

Government intervention in apprentice training may be needed to deal with the increased numbers of the early 1960s; for instance, a compulsory levy for a scheme of 'industry apprenticeship', in place of apprenticeship to individual firms willing to take this burden.

3. A greater interest by the universities in finding the best form of education for future managers would be welcome. We note that it is now often assumed in the non-science faculties of universities that study loses its educational value if it has a vocational purpose, and that in consequence the vocational needs of particular professions need have little attention. This assumption was not so frequent half a century ago, when degrees in commerce were instituted in several universities; thus, Alfred Marshall, in commending the Tripos in Economics, instituted in Cambridge in 1903, dealt with it as follows:

> 'A man is likely to be more efficient in business who has braced his mind to hard work in subjects that have no connection with it, than if he had occupied himself with an enervating form of technical instruction, however directly that might bear on his after work. But, provided the studies be themselves of a truly liberal character, the closer their bearing on his after work, the more active is his interest in them likely to be during his stay in Cambridge and in after life.' [1]

It is surely likely that liberal studies could be devised with a closer bearing on the 'after work' of a potential manager than any which at present exist.

4. We should like to see an increased scientific content in general education at all levels. The fully educated citizen should, we think, have some knowledge of science (whether general or specialized) as well as of the traditional arts subjects. The easiest way to accommodate the change would be to extend the period of education, for some by later leaving from grammar schools, for others by an extension of further education after leaving school; or, in a less discriminate way, by a raising of the school-leaving age. The form which the change should appropriately take, in schools of different types, is a matter calling for study and research, in which the British Association might ap-

[1] *Introduction to the Tripos in Economics and associated branches of Political Science*, Cambridge University Press, undated pamphlet.

propriately help, and the study should not forget the need of the scientist for a grounding in arts subjects.

5. By far the greatest obstacle to any such change is the shortage of science and mathematics teachers, which makes it difficult to educate science specialists, let alone to provide general instruction in science for the whole school population. We have heard no convincing suggestions for alleviating this shortage, other than by paying science and mathematics teachers (and if necessary other teachers) more. To say this is not to assert that teachers do, or should, teach only for the pay; a man may have to choose between a vocation to teach and a sense of obligation to his family, and it is not reasonable to expect that family obligations will always come second. Furthermore, the poor financial prospects in the teaching profession, with their accompanying difficulties in buying books, travelling, and maintaining membership of professional societies, are a means by which society shows that it gives teaching a low status; and we think that the sense of being a 'depressed class' has an effect which is added to the direct discouragement of low pay. We note that the U.S.S.R. maintains its extensive teaching of scientific and technological subjects not only by direction, but by paying the teaching profession well and giving it a high status.

We have examined this question in some detail. A comparison of the pay of teachers and of members of the Scientific Civil Service shows that teachers have comparable starting salaries, but considerably poorer prospects, even when account is taken of special responsibility allowances. After about seven years, the teacher starts falling behind; in the later stages of his career he may well be £600 or more behind the Civil Servant. The teacher may, of course, become a headmaster, but the number of scientists reaching this position is not enough to make a significant difference to the picture.

We estimate that the extra cost of paying science teachers on the Scientific Civil Service scales would be of the order of £13 million a year. If it was necessary to upgrade all graduate teachers (and thus to open the differential between graduate and non-graduate, rather than that between scientist and non-scientist) the cost would be considerably increased. The issue here is whether teachers should be paid their market value, i.e.,

according to supply and demand, or whether they should be paid according to some abstract standard of justice which requires equal treatment within a profession, and a close relation of salary to age, rather than ability. There is much to be said on both sides. Whichever way the decision goes, we think that the consequent Budget burden (including the necessary increase in the block grant to local authorities), and the full implications of the chosen increase of differentials, should be accepted; for even at its highest figure, the cost to the nation seems likely to be much less than the loss which will be suffered if science teaching is inadequate.

Some subsidiary points are worth mention. First, the present shortage could be alleviated a little by making a much better provision for numbers and salaries of laboratory technicians in schools. Second, terms of employment for part-time teachers, some of whom might be released by industry, should be improved; this would help technical colleges in particular. More might also be done to encourage the return of older married women to the profession. Third, there is a need for competent teachers in general science in the lower forms of schools, and it is important, therefore, not to put all the stress on the need for scientific specialists. Fourth, one obstacle to the extended teaching of science is the weakness of pupils in mathematics. We have the impression that not enough is known about the causes of success and failure in mathematical studies, and we hope that this matter is being fully investigated.

6. We have not been able to say whether the latest plans for the expansion of higher education in science and technology are a reasonable response to the needs of industry. This attitude stems in part from our doubts about the adequacy of a statistical approach; these doubts carry with them the implication that *flexibility* is most important. The educational system should not be expected to produce young people like a series of keys, each shaped to open a particular lock (which may after all turn out not to need opening), but rather like master keys, capable of varied use in the unknown future circumstances of industry. In consequence, specialization must not be carried too far in school or university or technical college. But our inability to judge the adequacy of plans for expansion is due also to the fact that very little is known about the way in which scientists are used in in-

dustry. Industry itself has not thought very deeply about the best ways of using scarce scientific personnel; and we think that in places graduates and other highly trained staff are being misused, partly because of the shortage of technicians. Effective research on the use of scientists and technologists would make the planning of educational facilities much more reliable.

CHAPTER 12

Taxation Policy

THE conclusions from our earlier studies,[1] made in the period 1953–56, may be summarized as follows:

(*a*) It is difficult to identify the harmful effects of high taxation in draining away money which is needed for the finance of technical advance, but there is no ground for complacency on the matter; some firms are certainly affected. It is possible that taxation hinders advance precisely where that advance is most needed; and it is at least ready to hand as an excuse for inaction.

(*b*) In activities at home no great weight should be attached to the direct effects of high taxation in discouraging the adoption of new methods—that is, to the 'disincentive' effects. Taxation does tend, however, to raise the general level of prices which a company sets for all its products, and thus to restrict potential markets for new products; and high tax rates lead to a bias in favour of quick returns. In activities overseas the relative British and foreign tax rates are certainly important.

(*c*) Heavy taxation of expenditure (e.g., purchase tax) may distort relative yields and make inefficient methods financially attractive. It may also so limit an industry's markets as to make it impossible for that industry to adopt new methods which would otherwise be desirable.

(*d*) The effects of taxation on general business sentiment, though variable, are important; and large *changes* in taxation (e.g., in initial or investment allowances) are a disturbing factor.

(*e*) There is no ground for regarding the British system of depreciation allowances for tax purposes as a special hindrance to development. (We shall, however, discuss whether they could be modified so as to encourage development.)

[1] See Chapter 13 of *Industry and Technical Progress*.

(*f*) There is a likelihood that the weight of estate duties is a hindrance to the adoption in certain firms of improvements to products and processes.

These conclusions are based on the evidence of a period which was generally optimistic, and in which financial restriction, though of growing severity, had not yet been felt by many firms. Our views have been criticized by some who think that we greatly underestimate the difficulties and obstacles produced by high taxation; and we concede that developments of the policy of credit restriction in the years 1956–58 made many firms more conscious of financial stringency, and more resentful of the rapacity of the tax-gatherer. But renewed inquiries in that period showed that there certainly remained numerous and important firms whose financial position was such that they could not reasonably offer high taxation as a reason for slowness in technical advance. Whatever extra weight has to be placed on the harmful effects of taxation, we still cannot encourage the view that the harm is universal.

The weight of taxation is jointly determined by the size of Government and local-authority expenditure, and by the surplus or deficit which (mainly on the decision of the Chancellor of the Exchequer) is considered appropriate for the accounts of public authorities. In most post-war years taxation at the level needed to balance the ordinary Budget would in the judgement of the Chancellor have left in the pockets of the people money whose spending would have created an excessive demand and a rise in prices. Taxes have therefore been fixed at a level which yields a substantial surplus; the existence of this surplus in the ordinary Budget has lessened the need for Government borrowing for capital purposes (e.g., for house-building or for the development of the nationalized industries), and has thus made it easier to find room for the claims on the capital market by private industry. But in other circumstances it is appropriate if the Budget accounts, or the accounts of all public authorities taken together, show a much smaller surplus, or even a deficit. Thus in 1959 there was considerable idle 'excess capacity' in industry, and some unemployment; it was considered possible to increase output without causing large price rises or upsetting the balance of payments. This therefore was an occasion for

reducing the Budget surplus, so that extra spending by consumers could call forth the extra output.

In discussing the weight of taxation, it must be recognized that the purposes for which the taxation is levied have their effects on technical progress. Government expenditure is dominated by spending on defence and on the social services. Spending on defence research and development obviously has profound effects on the rate of application of scientific knowledge in industry, in (for instance) the field of atomic energy, in metallurgy, and in the manufacture of aircraft, machine tools, and control systems.[1] Spending on education is also a very significant factor in technical progress; and minor claimants on the Government purse are the research organizations, whose importance is discussed in Chapter 10. The general presumption that lower taxation would, in some firms at least, favour technical progress is therefore subject to a rider: 'provided that spending of greater importance to that progress is not thereby sacrificed'. It is possible, indeed, that a small increase in taxation (or a lessening of a reduction which might otherwise have been possible) might on balance favour technical advance, if (for instance) it was required to provide for developments in education.

Nor can we regard as irrelevant the decision to have a surplus or deficit. In so far as this is successful in preventing disastrous inflation or a severe slump, or in keeping the country from crises in its balance of payments, it is creating conditions of ordered stability which are favourable to technical progress. The post-war policy of large surpluses has been at times and to some extent a policy of limiting consumption in order to make room for investment; in so far as technical progress requires high investment, such a policy is in its favour. (It is only fair to add, however, that at other times the policy has appeared to be one of limiting investment in order to make room for consumption.)

It is often argued that the raising of a great surplus so inhibits personal effort and corporate enterprise, and so reduces the

[1] This does not, of course, mean that the present level of defence expenditure is the best from the standpoint of those who desire technical progress in industry. A high proportion of our scarce supply of scientists and technologists is absorbed by the defence effort. If a change of defence policy allowed some of this scarce man-power to be released, technical progress in industry could be speeded up.

possibility of expansion, that the Government should take the risk of a very large reduction of taxation, expecting shortly to be justified by a leap forward in the national product. This is the view implied in the phrase 'taxation is the cause of inflation, not its cure'. The risk involved in such a change of policy is a complex one, involving (for instance) the question of whether the country could pay for the resulting rise in imports; the prize for risk-taking in tax reduction is at the time of writing held by the Budget of 1959, but it is not clear what effect it may have on technical progress. There is indeed no general proposition that a reduction of taxes will increase production, and no general proposition that an increase of production will quicken technical progress; each situation must be judged on its merits. As for the direct effect of a tax reduction on technical progress, we know of no sufficient evidence that taxation at its post-war levels weakens personal effort on balance—it probably makes some people work harder and others less hard; and, for what it is worth, our finding that the harmful effects of taxation on technical progress are certainly far from universal suggests that the advantages of lower taxation in stimulating technical progress would be patchy.

The argument of the preceding paragraphs shows how complex the effects of a change in taxation on technical advance may be, and how necessary it is to follow a path through the maze of complexities to its end—bearing in mind not only the immediate effects of a tax change but also the effects of any associated change in the spending of public authorities or in the surplus or deficit in their accounts. In what follows, however, we shall limit ourselves to the narrower subject of the immediate effects of taxation, and our conclusions can thus only be given direct application if the associated changes are assumed to be neutral in their effect on technical progress.

It is clear that, ignoring the associated changes, reductions in taxation are likely to favour advances of technique in some firms at least. They will do this—

(*a*) by allowing the retention of more profits, and thus making it easier to finance new products or processes, or

(*b*) by widening markets through a fall of prices or an increase of consumers' available income, or

(*c*) by removing or lessening distortions of the market, such as (for instance) are produced by purchase tax, or

(*d*) by lessening the importance of uncertainties, such as may arise from the need to pay heavy death duties, or

(*e*) by producing a change of business outlook or sentiment, not necessarily fully explicable or rational, but of a kind favourable to change and to long-term planning, or

(*f*) by stimulating individual saving and thus making it easier to raise capital, or

(*g*) by a combination of these.

These means of influence are so various that almost any reduction of taxation can be expected to have some favourable effect on technical progress in some part of the economy. Can we, however, select the reductions in taxation for which this effect will be strongest and most widespread? We have reviewed the numerous possibilities, and the following paragraphs summarize our conclusions.

Since it is the *young* firms and the *rapidly growing* firms which are likely to be especially conscious of financial stringency, we must look first at tax concessions which favour these classes. The smallest business units—individuals or partnerships—are most likely to be helped by reductions in the standard rate of income tax or in the rates of surtax; reductions in surtax also have the merit of stimulating personal saving (which is dominated by the saving of the rich) and thus of freeing funds for private or stock exchange lending or for the starting of new businesses. There appears to be no practicable way of helping young and vigorous small companies which does not also help moribund small companies; an example of a general help to very small companies would be an increase in the starting-point and the range of abatement for profits tax. The devising of special means of help for growing firms is difficult, for it is not certain by what standards growth should be measured. The most hopeful method would seem to be by an extension of the principle of the investment allowance;[1] and this could be made to serve the

[1] I.e., an allowance which causes the amounts set off against profits over a period of years to allow for the depreciation of assets to exceed the original cost of the capital assets purchased. We have evidence of the effectiveness of the investment allowance, when first introduced, in stimulating firms to think of capital investment, and hence incidentally to introduce new methods.

special needs of small firms by giving (subject to safeguards against evasion by larger firms) a higher rate of allowance on the first £20,000 or £50,000 of capital investment.

Apart from these special proposals, the best ways of lessening financial stringency or stimulating a mood of expansion would seem to be in reductions in the standard rate of income tax or in profits tax. The trouble about such concessions, however, is that they tend to be very widely diffused, and therefore are usually small in their effect on a particular firm. They are also arbitrary in the help they give, because the profits of companies vary so much with chance circumstances beyond their control; and they give no help at all, of course, to the company which is making a loss.

The discriminatory heavy taxation of particular products (such as arises from purchase tax) is likely to affect the application of the results of scientific and technical advance in three ways. First, the general effect of high discriminatory taxes is to inhibit the growth of the trades chosen for taxation, and in so far as technical progress depends on the size of the market, such progress will be slowed down. Thus the rate of application of new ideas in the automobile industry would almost certainly be greater if the market were enlarged by the removal of purchase tax. Second, most such taxes create curious 'boundary effects' between a product and its less highly taxed substitutes. Some of these boundary effects appear to be a nuisance or waste rather than a hindrance—for instance, the encouragement to householders to use large industrial immersion heaters, or the loophole (now closed) which produced a cheap station wagon by cutting windows in the side of a van. But in some cases there is a positive encouragement to adopt a technically inferior method; we quoted in *Industry and Technical Progress* the case of the tax incentive to use the relatively inefficient kerosene-burning tractor. The third effect of heavy discriminatory taxation is to create exceptional incentives for fraud and evasion, and in some trades the position of respectable and established firms is reported to have been seriously shaken by the activities of small competitors willing to give false invoices. Such dishonest firms are hardly likely to be specially interested in long-term technical advance; their interest is in quick and large profits.

We conclude from this that the lowering and equalization of

taxes on items of expenditure would be likely to favour technical progress. A small tax, widely spread, and without large differences in tax rates for similar products, is to be preferred to a heavy and narrowly based tax on items of expenditure.

There is no doubt that, on the evidence we have received, a large reduction in the rates of estate duty payable on large estates which consist mainly of business assets would, in certain firms, set the owners free to employ their profits on the development of new products and processes. They would no longer be so much obsessed by the need to pile up cash for the payment of duty (in order to avoid loss of family control) or by the short-term views encouraged by the knowledge that the business must be sold on the death of its owner. But it must be remembered that the forced sale of assets on death is not only a hardship to the progressive firm; it is also frequently a means of bringing under livelier management firms which were becoming moribund. A large reduction of estate duty would not therefore be pure gain to the cause of industrial progress, and a *small* reduction (which is much more likely to be a practical possibility) might be of little use.

We can summarize the effect of this section as follows: if the general national situation allows of reductions in taxation, these reductions may be expected to be most effective in stimulating the use of scientific and technical knowledge in industry if they are of the following kinds:

(*a*) the reintroduction or extension of investment allowances;
(*b*) special concessions to small firms;
(*c*) the lowering and equalization of taxes on items of expenditure;
(*d*) lowering of the rates of surtax.

If *large* reductions are possible, the following are worth consideration:

(*e*) reduction of the rates of estate duty;
(*f*) reduction of the rates of profits tax;
(*g*) reduction of the standard rate of income tax.

If *increases* of taxation are required, they will be least harmful to the use of scientific and technical knowledge in industry if they

avoid changes opposite to those above; specifically, a reduction in the personal allowances for income tax would seem to have a minimum effect on technical progress, because it gives a tax increase whose main direct effect is on individuals and not on businesses, and whose indirect effect on business is likely to be widely diffused.

The next point for consideration is whether there are variations of the methods of assessing or raising existing taxes which would be on balance favourable to the adoption of new technical ideas. We have invited suggestions on this matter, but we have found only three practical and substantial proposals; this is perhaps natural, for the British tax system is elaborate in its concern for special circumstances, and in its slow development over the years it has not ignored the effect on technical progress. The first proposal is for a variation of depreciation allowances which might offer a special assistance or inducement to firms contemplating the adoption of new processes. The investment allowance in force in 1954 and 1955 [1] appears to have been a strong, if indiscriminate, inducement to undertake new investment; the various initial allowances in force before or since have also no doubt been of some assistance, if only by lessening the financial strain in the period in which new investment is undertaken. Sir Roy Harrod has suggested an instrument more flexible and selective than either of these.[2] He proposes that firms should be allowed to choose for themselves in how many years they wish to write off their plant, and this would determine the period of depreciation for tax purposes. An asset could, if desired, be written off in the first year; but it would be a rule that the same procedure would have to be followed in the firm's own books. But the amount to be written off would remain the historical cost of the asset, so that the Exchequer would not be giving a subsidy (as with the investment allowance), but only an interest-free loan (as with the initial allowance). The advantage would be the psychological stimulus and financial convenience of freedom of action. An investment of uncertain life or doubtful profitability would probably be written off quickly, for firms would prefer such assets to stand at a low figure in their books.

[1] Reintroduced in 1959; the effects of the reintroduction are not clear at the time of writing.

[2] 'Encouraging Selective Investment', *The Director*, June 1957, pp. 489–90.

Such a system operated in Sweden from 1938 to 1951, when (apparently because it was considered to favour investment too highly) it was replaced by a system equivalent to the British initial allowances. In judging its advantages, we must not forget the effect already produced by balancing charges and allowances. If a firm decides that a machine is obsolete before its 'Inland Revenue life' is up, the value not already allowed against profits (less the second-hand or scrap value) can be set against profits in the assessment based on the year in which the plant was scrapped. The financial difference between this and an option to write off the whole in the first year is the effect of delay in the tax relief.

Example: Asset costing £100; depreciation by 10 per cent. declining-balance method with 20 per cent. initial allowance (i.e., the initial allowance in force from 1956 to 1958); future allowances of depreciation discounted at 6 per cent. per annum; the machine to be scrapped with no re-sale value. Comparison of present value of allowance (including balancing allowance) with present value of allowance obtained with one-year write-off (i.e., the most favourable result of the Harrod system).

Year of disposal	Present value of allowances as percentage of those with one-year write-off
2	97
3	95
4	93
5	92
6	91
7	90
8	90
9	90
10	90

The difference revealed by this table as caused by a change to the Harrod scheme is not large, but we agree that the psychological stimulus might be more important. The Royal Commission on Taxation objected to 'free depreciation' on the grounds that the taxing authority surrendered control over the whole yield of the tax, and the power to attempt to influence investment by varying the initial allowance rates. The first of these objections seems to us ill-founded; uncertainty about the accounting practices of firms could hardly be as important as

the necessary uncertainty about the size of profits in a particular year. The second objection is more important, but we doubt if it is wise to seek to influence investment by sudden changes in the tax system, which are highly injurious to the security needed for long-term planning. Rapid technical progress is assisted if firms can be encouraged to take a long view. We do not therefore feel that the Harrod scheme can be rejected as easily as the Royal Commission rejects it. While we agree that its advantages are not overwhelmingly great, we think that it merits serious consideration.

The second proposal which we recommend for consideration is the provision of special investment allowances for development costs. The development or design stage of a new product or process is frequently difficult and expensive, and may involve the failure of costly pilot plants. It would, of course, be difficult to define the development stage, and some limit would have to be set on the grant of allowances for pilot plants which produce saleable products. But we think it desirable that the Revenue should be willing to take some risk in order to encourage the vital stage of development.

A third suggestion relates to estate duties. There is already power to accept landed property and works of art in place of a cash settlement of this tax. It is possible that the State may in the future agree to accept a much wider range of assets in payment of duty. Such an agreement would convert estate duty into an instrument of nationalization, rather than a true tax, but the duty would still serve its main purpose in lessening inequalities of capital resources. We naturally express no opinion on the general merits of so far-reaching a proposal, but it would appear to us that it would remove part at least of the harm done to technical progress, since it would no longer be necessary to draw large sums in cash from the resources of a firm during the lifetime of its owner, in order to provide in advance for the payment of duty.

Next we have considered whether there are, among various proposals for new types of tax currently under discussion, any which would bear lightly on (or even encourage) technical progress, and which should therefore be examined as possible substitutes for existing taxes. We find only one such proposal, namely a tax on capital gains—either on *realized* capital gains,

with allowance for capital losses, as in the United States, or on capital gains *realized and spent.* (The latter would be the main effective result of replacing surtax by a progressive expenditure tax,[1] though an expenditure tax discourages spending from income as well as from capital.) The net total of personal saving is produced by the balance of the activities of savers and dissavers, and there are undoubtedly some wealthy people who are maintaining an accustomed standard of living by dissaving, that is by living on capital—a process which is all too easy if there are capital gains to be realized and spent. The taxation of realized capital gains, and (still more) the expenditure tax, would discourage this dissaving; it would thus tend to increase the net total of personal saving, and there is a presumption that this would assist in the finance of technical advance—perhaps especially by making it easier for young and growing firms to find money.

Against this, we must set the argument that the prospect of untaxed capital gain helps to persuade people to engage in risky enterprises, and that investors would in consequence become more cautious if capital gains were taxed. This seems to us an indirect and uncertain effect, and we would give less weight to it. It is in any case doubtful if the argument applies to an expenditure tax.

On balance, therefore, we conclude that the taxation of capital gains, and (more strongly) an expenditure tax, might actually be favourable to technical progress; to the direct effect would have to be added the advantages gained from any compensating falls in income tax, surtax, or other taxes. We doubt, however, if the effects on technical progress should provide the main ground on which these tax proposals are judged, for the reactions of individuals to changes in taxation are not always logical or foreseeable. It is unfortunate that it seems to be impossible to conduct small-scale experiments in the field of taxation, and that the results of suggested major changes are therefore so largely conjectural.

Next we must consider selective reliefs. It is usually possible to stimulate progress in particular firms or industries by tax reliefs confined to those firms or industries. The use of the tax system in this way is, of course, an alternative or an adjunct to the use of

[1] That is, a tax on individuals based on their total *spending* instead of their total *income*, and therefore encouraging saving rather than spending.

subsidies, and there are many instances in which subsidies have been used as a means of aiding particular industries—agriculture and the cotton industry provide post-war examples. It is on the whole a wise principle that taxation should be seen to bear equally upon all in like financial circumstances, and that discrimination should be introduced, if at all, by explicit subsidy. The United States, however, has used differential 'write-off periods' as a means of encouraging growth (and presumably technical advance) in industries important for national defence.

The general question of special State assistance at key points in technical advance is considered in Chapter 9. Such assistance can certainly be given, if desired, through the tax system; but if it is given to a whole industry it may be rather a rough-and-ready way of encouraging progress. Despite the use of terms such as 'backward industry', it is almost impossible to define an industry without including both backward and progressive firms, and both firms in financial difficulties and firms with ample liquid assets. Concessions to particular industries may therefore help those who need no help.

Finally, it is a conclusion confirmed by our studies that the uncertainty created by tax changes and the expectation of tax changes has an unsettling effect on the planning of technical advance. The stimulating effect of investment allowances may have been greatly weakened for the future by the fact that they are now seen as a concession liable to withdrawal at the first shift of the winds of economic circumstance. No producer of highly taxed goods can be expected to be in the mood to commit himself to new products or processes in the months just before a Budget in which he has some hopes or fears of a tax change. The disturbing effects of expectations of purchase-tax changes have on occasion become so great that the Chancellor has been forced to reveal in advance of his Budget his intentions on this particular matter. While recognizing the desire of Governments to use taxation as a flexible instrument of control, therefore, we think that the harmful effects of frequent changes on the adoption of new ideas by industry should be given full weight. From the point of view of technical progress, it is desirable that the tax burden should be light; but if it must be heavy, let it at least have the virtue of familiarity. It is best if tax changes are as infrequent and as small as possible.

CHAPTER 13

Credit Policy and the Capital Market

THE next question to which we turn our attention is whether the operation of credit policy and the facilities of the capital market can be improved so as to speed up technical progress. Our studies were begun in a time of relatively easy credit, and continued through the successive stringencies of the 'credit squeeze'; our report is being written in a time of renewed relaxation of credit. It might seem that we would have obtained good evidence of the effects of credit restriction on technical progress. But in fact we found that a large proportion of the firms we examined retained a position of comfortable liquidity throughout the period of restriction; others, though needing access to outside capital, were of such a standing that they could be undisturbed by doubts about their ability to raise it from the public. Serious difficulty in raising money to finance new products or processes was felt by only a minority of firms, but it was an important minority, for it contained some markedly progressive companies which were outgrowing the possibilities of small-scale private finance but which were not yet attractive to institutional or public lenders.

Credit restriction is a kind of rationing, and there are two kinds of rationing—by direct control of quantity and by price. Both methods of restricting the flow of money have been used in the United Kingdom; the first by (for instance) directives to banks about their lending, control of hire-purchase transactions, and the restrictions operated by the Capital Issues Committee, and the second by high rates of interest. We found little direct evidence of the regulatory effect of rates of interest,[1] partly because decisions to invest in ventures involving technical progress are frequently not 'quantified'—that is, there is often no direct comparison of an expected yield with the cost of raising money; and partly because, where a figure is set to an expecta-

[1] See *Investment in Innovation*, pp. 144–6.

tion of yield, it tends in a progressive industry to be high—frequently as high as 20 per cent.—and is not greatly affected by such moderate changes in the cost of raising money as have occurred in Britain in recent years. We thought it likely, however, that the control exercised by rates of interest would 'bite' in circumstances of uncertainty:

> 'Where business expectations are firm and decisions are easily arrived at—either to expand, when demand is high, or to do nothing, when there is a slump—rates of interest would have little controlling effect; at the intermediate stages of doubt and uncertainty their effect, though far from universal, might be much more significant.' [1]

The rationing of money by directives to banks or other means is a way of influencing the institutions of the capital market, and it is appropriately considered alongside any deficiencies or gaps in those institutions. In what ways may technically progressive firms be frustrated by difficulties of raising money?

We found two types of frustration, *absolute* and *conditional*. Absolute frustration occurs when the firm is unable to raise money on any reasonable conditions, and we found this to happen:

(*a*) in very small firms which have not had the good fortune to find a private lender;

(*b*) in somewhat larger firms, requiring more than can reasonably be obtained from a bank or from private lenders, but too small to be of much interest to City institutions, and not appropriately capable of being assisted by hire-purchase finance;

(*c*) in small but extremely active firms, outgrowing their financial strength, and too young or growing too quickly to appeal to conservative lenders;

(*d*) in firms of any size which in a period of credit restriction have operations which do not fit in with current theories of the 'national interest', as interpreted in bank directives and the policy of the Capital Issues Committee.

Conditional frustration, which is much more frequent, is found in firms which are unwilling to stomach the conditions on which they could raise money. The belief that 'he who pays the

[1] *Investment in Innovation*, p. 146.

piper calls the tune' is held with a fervour which is at times unreasonable; we have found firms which are short of capital but have never troubled to find out about the institutions which might help them, because they are so certain that they would lose their independence. Many family firms are afraid to lose family control; other companies are afraid of outside interference in policy if they accept outside help.[1]

Frustration is also felt in nationalized industries, and we have concluded that the frequent changes in Government policy relating to the supply of capital to these industries are likely to be harmful to technical progress.[2] More generally, sharp changes in credit policy (like other substantial changes in Government economic policy) are likely to create an atmosphere of uncertainty not conducive to the long-term thinking and planning which technical change may require.

Finally, it is worth making a distinction between the problems created by the absence of facilities for raising capital and the problems created by the *imperfect working* of those facilities. We thought that some of the institutions concerned with the supply of capital tended to be over-confident of their ability to make a valid technical assessment of projects placed before them, and it would not surprise us if some frustration of technical progress is caused by their mistakes.

What are the implications of these remarks for Government and general policy? First, it must clearly be said that (other things being equal) easy credit—comprising both low rates of interest and the absence of quantitative restrictions—is likely to be favourable to technical progress. It will at least impose no barriers to technical change in those firms which in the circumstances of the time find themselves needing outside capital. Second (other things being equal), *stable* credit conditions are likely to be favourable to technical progress, by reducing the uncertainty of long-term planning.

The Government itself has an interest in stable and easy credit, being one of the greatest of borrowers; but (of course) there must arise circumstances in a country with great international trading and banking connexions when variations of credit conditions are necessary, perhaps for causes which are

[1] See the examples in *Industry and Technical Progress*, pp. 140–1.

[2] See *Investment in Innovation*, pp. 34–36.

wholly external. If from time to time it is necessary for credit to be restricted, are there means of making things easier for firms with the ability to undertake valuable technical changes?

We doubt if this can be achieved by decree, by defining in advance that the demands of certain industries shall be regarded as in the 'national interest'; for we doubt if the corporate wisdom of Government can be trusted to know in advance all the places where valuable technical change is likely to occur.[1] Since the financial needs of firms are a complicated resultant of their needs for expansion, for technical improvement, for stock finance, and so forth, it is not easy to deal with the matter by giving favourable consideration to loans for technical improvement, though in some instances this might be done. But on the whole we think that, if credit restriction is needed, the rationing of money by its price (that is, by a high rate of interest) will, if it is possible, be likely to do less harm to technical progress than any alternative method. We take this view, first, because rationing by price does not arbitrarily exclude, by prior administrative decision, any borrower, and is therefore flexible; and second, because we observe that projects coming forward in progressive industries often show a markedly high yield, and rationing by price would therefore be less burdensome to those industries. In order that the control exercised by rates of interest should 'bite' over a greater range of circumstances, it might be necessary to contemplate rates much higher than those usual in Britain; and since (as we have mentioned above) the 'price of money' might not even then have a universal effect, some quantitative restriction might be needed in addition. We think that it should be of a simple and largely non-discriminatory kind.

We hope, however, that in normal circumstances Britain can enjoy a general ease of credit. The possibility of improving the machinery of the capital market must still be considered. There is a virtue in the variety of credit-giving institutions, and any tendency to simplify the structure of the market so that a given class of borrower is dealt with by a single lender should be deplored; for it would mean that there was no protection against the mistakes of the single lender, perhaps due to his having taken faulty technical advice about a project, or due to an

[1] Though a greater attempt should be made to identify *some* of them; see pp. 103, 106.

unnecessary degree of conservatism. Furthermore, a variety of credit-giving institutions competing for business may do something to dispel the fear of asking for financial help which is involved in 'conditional frustration'. We would also like to see publicity, aimed at the business-man, and designed to show (what we believe to be the fact) that the obtaining of help from City institutions does not necessarily mean any serious loss of independence of policy.

We think that the institutions of the capital market are reasonably comprehensive,[1] though if there were more of them it might be easier for a really lively young firm to obtain timely and adequate help. The point of weakness is right at the bottom end, at the level of people who usually depend on individual private lenders or on small bank loans. It is worth considering whether there is not a need for an equivalent to the American 'Small Business Administration', which makes long-term loans at favourable rates of interest. The S.B.A., however, helps businesses which in British conditions would look to the Industrial and Commercial Finance Corporation or to other City institutions for aid—it can make loans up to $350,000 to manu-

[1] See *Industry and Technical Progress*, pp. 143–4. A firm in need of money should not give up hope until it has examined at least the following sources:

(*a*) Private lenders, who are often known to local solicitors, accountants, and bank managers.

(*b*) Banks: although bank finance is supposed to be for projects which are self-liquidating in a short time, it can often be used to release other resources to buy fixed assets; and at times the banks themselves will lend for the purchase of fixed assets, provided the risk seems limited.

(*c*) Hire-purchase finance companies, who will often finance the purchase of machinery.

(*d*) Extended credit from suppliers.

(*e*) Loans from insurance companies, e.g., for buildings.

(*f*) Loans from other industrial or commercial companies; these do not always involve loss of managerial independence.

(*g*) The Industrial and Commercial Finance Corporation, which exists to provide loan or equity capital for medium-sized and small firms.

(*h*) Bodies such as Safeguard Industrial Investments Ltd., Estate Duties Investment Trust Ltd., the Charterhouse Industrial Development Co. Ltd., and Private Enterprise Investment Co. Ltd. (managed by S. G. Warburg and Co.). These bodies will, of course, expect a satisfactory trading record and good management (with provision for continuity).

(*i*) Public issues on a provincial Stock Exchange.

(*j*) Public issues on the London Stock Exchange. This can be an expensive source of finance except for a company with a reputation already well established. It is not normally suitable for issues of less than £50,000, or for companies with assets of less than £100,000–£200,000.

facturers employing up to 250 people, to wholesalers with a turnover up to $5 million, or to retailers with a turnover up to $1 million. Possibly a corresponding body for *very* small businesses, making loans in the range £1,000 to £20,000, might find a useful place in the British scene; and might ease the path of men who have a real contribution to make to technical progress. We are not sure of this, but we think it important enough to warrant full investigation.[1]

Where the Government is directly responsible for the supply of capital, either from the Budget or by State guarantee, we think that the most important rule is to make plans for a period of years and to avoid frequent changes to suit the short-term needs of economic policy. We think that the insecurity of capital programmes is a serious handicap to the technical progress of the nationalized industries.

[1] There is a small-scale equivalent in the 'Revolving Fund' operated by the Board of Trade under the Conditional Aid Scheme for financing means of improving productivity. For reasons not wholly clear to us, this has not been a great success.

CHAPTER 14

Protection against Foreign Competition

A NUMBER of British industries enjoy partial or complete protection from foreign competition. This protection takes various forms, the principal ones being tariffs, quotas, import licensing, and subsidies. The British tariff shows the marks of its historical origins: the high McKenna duties of 1915, imposed on luxuries to ease pressure in war-time; the duties under the Safeguarding of Industries Act of 1921, imposed to deal with problems arising from depreciated currencies and to lessen dependence on foreign sources of supply of essentials; the general *ad valorem* tariff under the Import Duties Act of 1932 (subject to numerous exceptions), which was the protectionist answer to depression; the principle of Imperial Preference, finally stated in the Ottawa Agreements of 1932; and the special provisions for action against 'dumping' (i.e., the continued sale of foreign products at prices not covering their average cost of production). The tariff system has, of course, been affected by the post-war negotiations under the provisions of the General Agreement on Tariffs and Trade, and by such things as the agreement with the European Coal and Steel Community; it will no doubt be further changed by the events which have followed the creation of the European Economic Community. The legal basis of the system is now contained in the Import Duties Act of 1958, and its details can be found in the Import Duties (General) Order of that year (S.I. 973, 1958). It is a curious mixture of protection for key industries, protection for luxuries, and a general tariff on manufactures.

In general, the British tariff is imposed on manufactures and semi-manufactures (though, as we shall show, other forms of protection apply for agricultural products); and, of the total of manufactured goods, about a third have the advantage of Commonwealth Preference, and nearly all of these enter free. A further 21 per cent. of total imports of manufactured goods

in 1956 entered free from foreign countries, being for the most part metals and chemicals which are the raw materials of other industries. Twenty-two per cent. of imports entered against tariffs of less than 20 per cent. *ad valorem*, and 23 per cent. against tariffs of 20–50 per cent. Typical goods entering against a high tariff are motor vehicles, cameras, scientific instruments, watches, and clocks; but of course it is impossible to tell, without a detailed knowledge of British and foreign costs, which British products are given effective protection by the tariff. The absence of substantial imports of a product may mean that a tariff is effective, or that it is not necessary, British costs being in any case lower than foreign.

There still survives a considerable list of goods which are subject to import licensing. The objects of licensing appear to be partly to conserve scarce currencies (e.g., the former restrictions on dollar imports) and partly to protect home producers (e.g., the quota for apples from Western Europe and North America, which in 1958–59 provided for a concentration of these supplies in the first half of the calendar year); some of the licences appear also to be required as instruments of bargaining with countries with State-regulated trade. The licensing system varies from the Open General Licence (i.e., unrestricted import, with the possibility of control held in reserve: 'cash registers from the Relaxation Area' is a recent example) to the full system of individual licensing, e.g., for many goods from the Republic of China. For many products licences are granted to established importers to fill a certain quota; recent examples are quotas for canned grapefruit and apples, for coffee, and for dried fruit from the dollar area; for salmon and crab from the U.S.S.R.; for certain cotton manufactures from China; and for fresh apples and pears from Argentina. The quotas sometimes relate to quantity, but more usually to value; this value is sometimes c.i.f. and sometimes f.o.b., and is occasionally expressed in a foreign currency. The quotas apply to goods of a particular origin, or place of consignment, or both; they are limited in time, and (as in the example of the apple quota, mentioned above) they may be used to smooth out supplies. Thus the system of import licensing is complicated; it is also subject to frequent change, and it is difficult to judge its overall effect.

Protection by subsidy may be considered to have started, in modern times, by the grant of the beet-sugar subsidy in 1925. The strategic argument for the protection of British farmers is supported by the desire to economize on imports from hard-currency areas, by the desire to support farming as a way of life and to prevent the decline of rural areas, and by the straight political argument for helping a substantial pressure-group; it must be remembered also that agricultural protection is a world-wide habit. During the period immediately after the War some part of the food subsidies could be regarded as a social service to consumers; but now that most agricultural commodities are plentiful, the £300 million per year spent on subsidizing British food and agriculture must be regarded as mainly a protective measure.

For particular commodities, additional protection may exist if the Government or a statutory agency is the sole permitted trader and chooses to give priority to British goods. Thus from 1942 the Jute Control was the sole importer of jute goods, and exercised its power so as to import only that volume of goods necessary to bridge the gap between home demand and home production. It would appear that, where agricultural commodities are controlled by a marketing board, imports are regulated so as to 'fill the gap'; and if the estimate of the gap is made by an organization dominated by British producers this system is capable of giving a concealed protection. It is possible to identify yet other methods of protection—for instance, the help given to the British film industry by the system of quotas of home-produced and foreign films.

There is much in all this to justify the fears of the old Free Traders, that once the principle of protection is admitted its tangled and many-branched growth will create a jungle of restrictions; for a jungle remains, even after all the post-war efforts to liberalize trade and to lower barriers. For our present purposes, the questions which are of interest are: Has protection an effect on technical progress? If so, is this effect adequately considered in deciding the policy of protection?

Our studies lend no support to the idea that there exists any general principle that protection favours or retards technical progress. As we pointed out in *Industry and Technical Progress* (p. 187):

'the imposition of the McKenna duties appears to have been a condition, though not a sufficient condition, for scientific change in the paper-making industry. In the jute industry, the greater security given by import controls and by Government purchasing has freed managers from the immediate struggle for existence, and they have been able to give attention to the introduction of new equipment which had been developed in other industries.'

The technical progress of the farming industry has been very considerable; and although this cannot be ascribed simply to the system of subsidy and protection, it is most unlikely that the results of agricultural research would have been applied so extensively if protection had been withdrawn. In a competitive depressed industry, which lacks the stability necessary to encourage long-term developments, and which goes on using old methods because the order book is short and it is never certain if it will be refilled, protection against foreign competition may be a first step towards creating a stability favourable to technical progress; it will be a necessary, but not usually a sufficient, condition for that progress.

Occasionally the grant of protection can be used as a means of encouraging progress; thus in the pottery industry the Import Duties Advisory Committee made protection conditional on the formation of a Research Association.[1] No doubt the subsidies to the cotton industry, announced in 1959, can similarly be regarded as an indirect means of inducing technical progress.

It might seem that examples of the harm done by protection could be found by looking at some of the backwaters of industry, where firms produce traditional products for a secure market. The protection in this case, however, is often that given by specialized trade contacts and by being too unimportant to attract the attention of foreign competitors; we are unable to produce a good case in which the repose of a backward firm is clearly due to protection. But we think that there is a *prima facie* case for supposing that harm is done where a fair (but not large) volume of foreign products is sold on technical quality, despite a considerable price-differential in favour of the British product. Thus the fact that a fair number of British motorists prefer foreign cars, and that American technical assessments of

[1] See *Industry and Technical Progress*, Appendix III.

smaller European cars frequently rate the engineering quality[1] of British cars well below that of their German, French, and Italian competitors makes us wonder if the degree of protection given to the motor industry—higher than in Germany, France, Sweden, or the United States—can really be justified. It is possible that some consumer preference for high-priced French, Swiss, and Italian fabrics should be taken as showing a weakness of British design which would disappear more quickly if protection were less; but this problem is complicated by the existence of the very cheap Eastern sources of supply. The slowness of the British motor-cycle industry to respond to the challenge of the scooter is perhaps related in part to protection.

These are no more than conjectures; but, as in the matter of restrictive practices (discussed in the next chapter), we think that they sufficiently suggest that every case must be examined in detail, without preconceived ideas of the effect on technical progress. The question of policy which arises is therefore whether the possible influence on technical progress is sufficiently considered in imposing, continuing, or varying protective measures. The main forces which shape the protective system are the representations of interested parties, and the international obligations of the Government (e.g., under the General Agreement on Tariffs and Trade)—in particular, the desire to use concessions to obtain reciprocal concessions for British exports. In this process of bargaining, short-run questions of harm or benefit are likely to get much greater weight than the long-run effect on innovation. An industry seeking protection will assert that unemployment is already being caused by cheap foreign imports, or that productive facilities which might be needed in the future are already being closed down; its case will be stronger if it can assert that foreign competition is in some way 'unfair', being based on false costings or on the exploitation of cheap labour. We do not see who, in the present system, would represent the point of view that foreign competition may be a healthy stimulus to innovation, or alternatively, the point of view that the long-run progress of the industry depends on the stability given by protection.

Under earlier legislation, the function of acting as an in-

[1] But the styling may be better; British small cars do, at times, sell well in America.

dependent watchdog in relation to import duties was given to the Import Duties Advisory Committee; but this body apparently ceased to be used in or before 1939, and it was abolished by the Act of 1958. We are not sure that this abolition was wise; broad questions of public interest may in practice be safe in the hands of anonymous officials, but they are not publicly known and seen to be safe. The 1958 Act states, in s. 1 (2), that:

> 'The Treasury and the Board of Trade, in considering what import duty (if any) ought to be charged on goods of any description, shall have regard . . . to the desirability of maintaining and promoting efficiency of production in the United Kingdom. . . .'

This principle needs broader application. The long-run effect on technical progress should influence the decisions of Departments, not only about tariffs, but about subsidies, quotas, and other means of direct or indirect protection; and it should not only influence the initial decision but should also be regarded as creating a need for its periodical review.

CHAPTER 15

The Control of Restrictive Practices

WHEN we discussed restrictive trading agreements and monopolies in *Industry and Technical Progress*, we reached the following conclusion (p. 169):

'Technical progress is encouraged by a favourable balance between safety and competition, the nature of the balance required depending on the circumstances of the industry. Expansion is a favourable influence, but neither free competition nor monopoly can be singled out as necessarily encouraging technical progress.'

At that time, we had before us (in addition to the evidence of our industrial case-studies) the reports of the Monopolies Commission, from which we gained the impression that the strength and importance of restrictive agreements—at least of those investigated by the Commission—could be greatly exaggerated; and that the dangers to technical progress were to some extent hypothetical, being dangers which might reasonably be expected to occur, rather than dangers which could be proved to have occurred. Since then, the operation of the Restrictive Trade Practices Act of 1956 has brought under review over two thousand restrictive trading agreements, which have been registered, and the slow process of bringing agreements before the Restrictive Practices Court has commenced. A number of important agreements have been abandoned, as being impossible of defence under the Act, and this abandonment has been particularly frequent since the first judgements of the Court.

Section 21 of the Act states that 'a restriction accepted in pursuance of any agreement shall be deemed to be contrary to the public interest' unless the Court is satisfied that it can pass through one or more of seven 'gateways' and that the advantage thus accepted by the Court is not outweighed by any detriment 'resulting or likely to result' to the public or to persons not

parties to the agreement. The seven 'gateways' do not specifically include any advantage to technical progress from a restriction, but it would no doubt be possible to bring such an advantage under section 21 (1) (*b*):

'. . . the removal of the restriction would deny to the public as purchasers, consumers or users of any goods other [1] specific and substantial benefits or advantages enjoyed or likely to be enjoyed by them as such, whether by virtue of the restriction itself or of any arrangements or operations resulting therefrom.'

More doubtfully, effects on technical progress might be relevant under 21 (1) (*e*) or (*f*), which apply if removal of the restriction would have an adverse effect on unemployment in any area, or on export trade. Any disadvantage to technical progress from a restriction can be used by the Registrar as a 'detriment resulting or likely to result' to the public, which might outweigh the advantages claimed by the parties to the agreement; it will be noted that it is not necessary to prove either advantage or detriment as a realized fact or certainty, but only to prove that on the balance of probabilities it is likely. On the use of section 21 (1) (*b*), a commentary on the Act observes:

'It is the practice in some trades or industries for manufacturers, under the protection of level prices, to pool information as to methods and costs of production and improvements in design or quality of products. In those circumstances, it may be argued that the public interest benefits not merely by the efficiency of an increasingly organized industry but also because the quality of the product is higher, or its cost to the public is lower, than would otherwise be possible; and that the removal of the restriction as to prices would inevitably put an end to the practice of pooling information and with it the continuance of those benefits to the public. . . . It would support the argument if it could be shown that a trend of prices substantially favourable to the consumer was attributable to improved technique resulting from the pooling of information.' [2]

The commentary goes on to suggest that the argument would be stronger if it could be shown that level pricing in the home

[1] This appears to mean 'other than the advantage which *prima facie* is deemed to arise from the removal of any restriction'.

[2] Heathcote-Williams, Roberts, and Bernstein, *The Law of Restrictive Trade Practices and Monopolies*, Eyre and Spottiswoode, 1956, p. 57.

market had, through increased efficiency, led to major gains in exports.

But now that the Restrictive Practices Court has given judgement in several cases and (to the pain and surprise of some Trade Associations) has treated the provisions of the Act as meaning what they plainly say and intend, it can be seen that the seven gateways into the realms of legal restrictive practice are indeed narrow. Thus in the case of the Cotton Yarn Spinners' agreement the Court would not accept as a substantial advantage of the agreement that it encouraged modernization. The Court held that

'the feeling of stability and confidence in the future which (the minimum price scheme) gives does make it likely that mills will spend money on modernization and encourages them to do so. Whether there are good grounds for this feeling, we need not say; we are impressed with the volume of evidence which shows that it is in fact the attitude of the mills. Modernization should lower costs and should therefore result in some ultimate benefit to the purchasing public. But it will not lower the price to the public until it is done to a sufficient extent to have an appreciable effect upon the operating cost margin; and that effect will inevitably be delayed until after the next costs investigation. Moreover, as we have already shown, a reduction in the price of yarn has either to be very substantial in itself or has to be combined with other reductions further down the line before it affects the public's purse. We have come to the conclusion that the advantage to the public in the form of cheaper and better goods to be derived from modernization resulting from the Scheme is not a substantial one and cannot therefore be brought within the Act.'

But on the other side of the balance the Court held it to be a disadvantage of the agreement that it caused an unproductive employment of labour and capital. Counsel for the respondents had submitted that 'waste of natural resources is too remote an effect of the Scheme to be classed as a public detriment'; the judgement comments: 'We do not agree. Excess capacity in any industry means short-time working and idle plant. It is in the public interest that labour and capital should be employed as productively as possible, and we consider therefore that the excess capacity in the cotton industry is a public detriment.' The Court held the agreement to be contrary to the public

interest, despite the finding (which was perhaps illogical) that the disappearance of the agreement would cause serious local unemployment.

Similarly, in judgement on the Agreement between the members of the Blanket Manufacturers' Association the Court considered the submission that the existence of a minimum-price scheme gave confidence in the future of the industry and tended to promote reinvestment in the modernization of plant and buildings. It held that 'whatever be the beliefs of members as to the reason for confidence which was lacking before the war, and we accept them as honestly held, in our opinion the expenditure of money on modernization is due only to a very small extent to the existence of this minimum price scheme, seldom operative'.

It is dangerous to generalize about the public interest; the circumstances of each separate industry will require most careful consideration. Our inquiries suggest, however, that it will often be difficult to prove a detriment to the public from the effects on technical progress of a restrictive agreement (or, indeed, a monopoly) in an *expanding* industry. In such an industry there will usually be people with a vested interest in innovation; technical pride will take the place of competition as an impulse to progress, and the expansion of the industry will make it easy to innovate in the process of installing extra capacity.

It must be emphasized, however, that the difficulty of proving 'detriment' does not necessarily mean that a restrictive agreement has *no* effect on technical progress, but simply that its effect is overcome by the other factors causing technical change. Thus we have noted one agreement in which common pricing was supported by 'exclusive dealing' provisions—that is, by giving discounts which are forfeited if purchases are made from non-parties to the agreement. We think that this would probably have hindered technical progress if the agreement had not been weakened by indirect competition from alternative materials. This in turn means that if the agreement had been effective in covering a whole group of materials instead of only one, it might have been a serious hindrance to innovation. It must always be remembered that the variety of types and coverage of restrictive agreements is very great; and also that the indirect competition of alternative ways of achieving a

result is frequently important in lessening the effect of an apparently strong agreement.

We think that it will commonly be difficult to prove that, in an expanding industry, the removal of a restriction would be likely to deny to the public a substantial benefit or advantage in the form of technical progress. An expanding industry already has, in its expansion, a condition which makes it easier to adopt new ideas; the effect of the additional safety provided by a restrictive agreement will usually be far from clear. While it is true that agreements for pooling information can conveniently be tacked on to price agreements, it is not obvious that all flows of information will cease if level pricing is abandoned; a considerable part of the information needed by industry comes from outside (e.g., from research institutes or from machinery suppliers), and information developed within an industry is often shared on payment of royalties. We know of no evidence which would prove that the spread of information is quicker in monopolistic than in competitive expanding industries.

The problem of static or declining industries, or those which have difficult and variable markets, is more complex. Some striking cases of 'parochialism' and of unwillingness to consider new ideas can be found in industries whose firms are in bitter competition with each other; other cases can be found in sheltered backwaters of industry, where firms making a specialist traditional product rest without immediate need to fear competition. We think that it could justifiably be argued in some competitive depressed industries that a restrictive agreement is a condition for technical progress, which is never likely to occur as long as firms are dominated by thoughts of excess capacity and the shortness of the order book. But this is not to say that the agreement is a *sufficient* condition for technical progress; it may be that what is really lacking is managerial capacity or scientific and technological staff, and that these deficiencies must also be removed before innovation is likely to flourish. Indeed, it is possible that the apparent support given to technical progress by a restrictive agreement would be found not to be needed if the industry had better managers and more scientific staff. Thus, it may not be easy to argue convincingly that the public would be denied 'specific and substantial benefits or advantages' if the restrictive agreement were to be removed.

Nor is it easy to argue 'detriment to the public', on the other side. We do not think that it is necessarily true that restrictive agreements protect inefficiency. They tend to protect those groups which have the strongest bargaining power in negotiating the agreement, and it will not usually be true that this power lies with the inefficient firms. We think that substantial cases of the suppression of innovations, whether by groups of firms or by single-firm monopolies, are rare. We concede that possibly the habit of mind which runs to the protection of a restrictive agreement may be 'associated with sluggishness in accepting new ideas'; [1] but this is not the same as saying that the agreement is sole cause of the sluggishness. The provision for research and technical education seems to us a far more important factor.

We admit, of course, that in particular industries it may be found that the issue of technical progress is of decisive importance in arguing for or against a restriction. What we are suggesting is that this issue will not be found to have a regular substantial importance, such as might justify a recommendation that the legislation against restrictive practices (and the associated investigations by the Monopolies Commission of single-firm monopolies and export-trade restrictions) should, for the sake of technical progress, be used more vigorously or changed. The present structure of the law must be justified on other grounds. The growth of opposition to restrictive practices and monopolies, which has been an interesting feature of British political thought since the War, may, however, prove to have a long-term indirect effect in favour of technical progress, simply because it forces managers to think; in the process of re-examining and of trying to justify their practices, something new may emerge.

In reporting on our earlier studies, we said:

> 'If a "labour restrictive practice" is regarded as something which issues from the conservatism of the unions, whatever the attitude of management, we must record that we have found no evidence which would justify the conclusion that such practices are a serious hindrance to technical advance. What we have found is that bad labour relations can be such a hindrance, expressing themselves in a suspicious attitude to change. . . . Our general conclusion is that the

[1] *Industry and Technical Progress*, p. 168.

hindrances caused by labour, though significant and in part removable by good management, cannot be regarded as a major determinant of the speed of scientific and technological advance, at least in the period 1945–56.'[1]

This conclusion was criticized by a number of our readers as giving an inadequate view of the seriousness of the problem of labour restrictive practices, and we have therefore made some further investigations in three of the industries said to be encumbered by such practices—shipbuilding, newspaper printing, and building. These investigations have not been easy, because employers have been nervous about talking about their difficulties, lest they should make them worse. Many labour restrictive practices are localized, and firms which have remained free of them do not wish to draw attention to the fact, lest the infection should spread. We present our findings, therefore, in general terms.

We have found no clear case of a straight refusal by labour to operate a new machine or technique; naturally the usual problem is not a refusal, but a willingness to work the new machine only on conditions, such as the maintenance of an excessive man-power. This may prevent the full economies of an innovation from being realized, but, on the other hand, it may stimulate further innovation designed to evade the difficulty in some new way. We have been made aware of the oppressive weight of demarcation rules, both in causing waste of time when jobs are unnecessarily transferred from one worker to another, and in discouraging managements from introducing new methods, lest they should cause demarcation disputes. We have also heard of alleged agreements to limit earnings or output, which might influence innovation by loading it with unnecessary costs.

It will be noted that all these difficulties arise from the fear of redundancy, and they might be reduced if management gave more attention to overcoming this fear. The demand here made on management is part of the larger need for thinking ahead, stressed in Chapter 8. A firm which fails to predict what skills it will require to operate a future development may at a critical stage in that development suffer from a shortage of workers with

[1] *Industry and Technical Progress*, p. 173.

the appropriate qualifications. Equally it may suffer from the resistance of workers to change; if the impact of new methods on the direct interests of the factory workers is treated as an 'Act of God', it will not be surprising if workers take action in an attempt to protect their own interests. Yet thought about the implications and the timing of the new methods may easily prevent trouble. If there is a prospect of increasing sales by lowering prices, labour-saving equipment may even increase the total demand for labour, in which case the workers concerned can be given guarantees of employment (barring circumstances such as a depression). Where the demand for labour is likely to contract, serious redundancy can often be avoided by reducing recruitment in relation to retirements and to the likely rates of labour turnover. Where redundancy is inevitable, adequate advance notice and generous grants on dismissal should be given. Such thought for the interests of workers helps to get their co-operation in technical change; and where firms take the trouble to think ahead they can do much to gain the confidence of workers by discussing well in advance the intentions and effects of their plans.

It is important to recognize that redundancy is sometimes inevitable, being founded in the inescapable fact that, because of technical change, a particular craft is of diminishing importtance; it may not be possible to re-train the workers concerned, because of the jealousy of other crafts, and in an industry which is not expanding fast, or which has a variable work load, natural wastage may be inadequate to run down the numbers in the craft quickly enough. Thus the problem of redundancy must not be dismissed as something which could be overcome by sufficient ingenuity; it may be beyond the power of the industry, by its own actions, to avoid dismissals or the employment of men at low productivity.

This, though it explains, does not excuse the attempts of some groups of workers to command the tide of progress to withdraw. We use the phrase 'groups of workers' deliberately, because, although some labour restrictive practices arise naturally from the union structure (e.g., from the division between shipwrights and boiler-makers) their incidence varies widely even with a small area; it would be misleading to speak of a national union policy on the matter. In building, demarcation disputes (and

perhaps attempts to 'go slow') arise on particular sites, but we are not able to point to any general obstruction of technical progress so caused. There might be such an obstruction in future if pre-fabrication became much more common. In newspaper printing the problem is one of over-manning in an industry which stands to lose greatly from strikes, and employers are clearly very conscious of the need to walk delicately in their relations with workers; but though innovation may be slowed down, there is no evidence that it has been stopped. In ship-building we have been able to identify one case in which a highly important and revolutionary modern technique has been 'left on the shelf' in one yard because of fears of demarcation disputes. We think that there is considerable evidence of excessive rigidity in the labour practices of this industry, and it is possible that this weakens the competitive position of British yards and thereby, in a vicious circle, increases the fears of redundancy which are the basis of the rigidity.

We have no doubt that isolated cases of labour restrictive practices can be found in many firms in many industries, and that occasionally these obstruct technical progress; but we still see no evidence that industry is so universally weighed down by labour restrictive practices that these must be regarded as a major obstacle to technical change. Nevertheless, the obstacle may be serious in particular industries and places. Can anything be done about it?

It is often regarded as unjust that employers should be subject to inquiry by the Monopolies Commission, or be forced to defend a case before the Restrictive Practices Court, while no similar machinery exists for exposing or prohibiting labour restrictive practices. We doubt if the difference of treatment can be founded on any abstract principles of justice; it is a matter of expediency, arising from the fact that, whereas the law can be enforced against employers, it is exceedingly difficult to enforce it against local groups of workmen. While it would be possible to declare certain labour restrictive practices to be against the public interest, we see no way in which such a declaration could be given practical effect. But the treatment of combinations of firms in restraint of trade suggests another line of progress. Before the Restrictive Trade Practices Act of 1956 the Board of Trade could at its sole discretion refer a restrictive practice to

the Monopolies Commission for investigation and report; and the reports of the Monopolies Commission, though their recommendations were enforceable by order, had their main effect by revealing the facts and bringing public opinion to bear upon those who were declared to act contrary to the public interest.

The Minister of Labour has similar powers in relation to labour problems, by the setting up of a Court of Inquiry; but this is a form of machinery appropriate to a particular labour dispute, usually used after normal means of conciliation or arbitration have been exhausted. Courts of Inquiry do, of course, expose situations of inefficiency caused by bad labour relations (e.g., in Smithfield Market), but we think that something wider is needed. We therefore recommend that the Minister of Labour should be empowered at his sole discretion to refer to a Commission of Inquiry the general state of labour relations (including labour restrictive practices) in any industry where it appears to him that these relations are such as to endanger efficiency, technical progress, or the competitiveness of British goods in export markets. The Commission would have to make elaborate investigations, more like those of the Monopolies Commission than the brief hearings of a Court of Inquiry, and to publish a report and recommendations—which might, for instance, include proposals for lessening the fear of redundancy, from which so much trouble arises. We would suggest that there should not be powers to enforce the Commission's recommendations, at least until it is seen whether public opinion and good sense provide enough pressure for their adoption. While we have no doubt that the trade unions would object to such wider inquiries, and would claim that they are unnecessary, we do not think that public opinion would support them in this view.

CHAPTER 16

Summary of Proposals

THE purpose of this chapter is to provide an analytical table of contents for those who wish to find their way quickly to our main suggestions for action.

PART I: ACTION BY INDUSTRY

Where a need for development or design is felt, but the firm does not itself engage in research, the following questions should be answered:

(1) Will the development problems strain against the limits of existing scientific knowledge? If so, is there a place to which the firm could turn for research help?
(2) Is the development likely to be within the technical, managerial, and financial capacity of the firm?

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(3) If the development is not within the technical capacity of the firm, can appropriate help be obtained from other firms, including (if necessary) full-scale trials of a new product? 19–20

Communication of Ideas

The receptiveness of firms to new ideas can be increased if they employ scientists and technologists in greater numbers and from more varied fields of interest . . 25

Experts in more than one field are especially valuable . 25

Opportunities of 'cross-fertilization' between experts in different disciplines should exist 25

Within a firm, personal contact is more effective than written communication 25

Effective communication (of science or technology or of management techniques) is itself a technique which must be learnt 25–6

Procedure for making sure that a firm is open to receive new ideas:

(1) Make a check-list of the fields in which the communication of ideas may conceivably be important to the progress of the firm.
(2) Consider how far receptiveness can be assured by employing relevant specialists, or by employing 'scientifically literate' managers.
(3) Examine adequacy of range of interest of specialists, and opportunities of cross-fertilization.
(4) Consider employment of trained information officer.
(5) Examine opportunities for personal contact of staff with specialists in their field (e.g., attendance at conferences).
(6) Make second check-list of types of *written* communication which are relevant in the firm's fields of interest (including pure science journals, abstracts, research association bulletins, 'discussion' journals, general trade journals, &c.). Cut this list down to reasonable proportions by eliminating sources of minor relevance or poor quality.
(7) Examine use made of written material, e.g., effectiveness of circulation.
(8) Check balance of spending between written communication and personal contact 26–30

Management of Research and Development

Innovation in Small Firms

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Small firms which do *not* undertake their own development should be ready:

(1) to look out for and receive ideas developed elsewhere;
(2) to make intelligent use of outside help . . . 66

This attitude is more likely if scientists and technologists are employed 66

Special attention to the 'communication problem' is needed 66–7

The possibility of 'chartering' research or development facilities to meet a special need should be remembered . 67

Good technical salesmanship can do a lot to help small firms 69

Financial Problems of Innovation

Failure to know costs or to do costing properly may mislead firms in production or investment policy . . . 70–2

The cost of variety should be more fully reflected in prices; excessive variety may hold up desirable changes of method 72–3

Firms which claim to be short of money have often failed to take the trouble to find out the sources from which they might get it. A firm should find out: (1) if the money is really needed; (2) what possibilities of raising it exist; (3) what conditions would be attached, and make its decision in the light of all the facts 73

Improvement of organization may have to precede the raising of outside capital 73

Procedure for making decisions about investment in innovation:

(1) Create and frequently revise a list of developed or nearly developed technical possibilities available for the firm's use.
(2) Remove those which are clearly not yet commercial possibilities; for the rest, make estimates in money terms of expected cost and yield. If the uncertainty is great give a range of estimates or attach a note about the uncertainty. Include 'dislocation' costs of introduction, advertising costs, costs of extra working capital.
(3) Calculate percentage yield or yields for each prospective development: or calculate 'pay-off periods' (but see note in text about when this is appropriate).
(4) Rank developments in descending order of yield, using judgement in dealing with the highly uncertain items.

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Government laboratories, should use the experience and funds of the National Research Development Corporation in placing development contracts. Occasionally it may be necessary to create State development companies to manage development in a defined field . . . 120–1

The powers of N.R.D.C. to stimulate research should be used with vigour to fill in gaps which may appear in the structure of industrial research, or to recommend to the Research Councils action for filling them. This function is appropriately carried by a body directly in touch with the economic, as well as the technical, problems of industry 121

Education

There should be increased attention to the education of technicians (comparable to that given to technologists). This involves an improvement in scope, efficiency, and attractiveness of facilities for Ordinary National Certificate work; continued pressure for more day-release for apprentices; and a multiplication of the routes by which a man or woman may become a technician . . 131

There should be a rapid spread of joint schemes for the training of engineering apprentices by small firms, and apprenticeship schemes might be aided by a tax remission proportional to the number of apprentices in training. Unless there is an early response to the need for an expansion in the intake of apprentices, other forms of Government intervention may be needed, such as a compulsory levy for a scheme of 'industry apprenticeship' . 131–2

There should be a greater interest by the universities in finding the best form of education for future managers . 132

There should be an increased scientific content in general education at all levels; its form requires further study . 132–3

The need to pay science and mathematics teachers more must be faced, even if it involves paying all graduate teachers more 133–4

There should be a much better provision for numbers and salaries of laboratory technicians in schools . . . 134

Terms of employment for part-time teachers should be improved 134

The stress should not be entirely on the recruitment of scientific specialists to the teaching profession; competent teachers of elementary general science are also needed . 134

Taxation

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Credit Policy

Easy and stable credit conditions are likely to be favourable to technical progress; but, if credit restriction is necessary, high rates of interest will probably do less harm to technical progress than the quantitative restriction of particular borrowers. Where quantitative restriction is necessary it should be as simple and non-discriminatory as possible 150–1

There should be more publicity for the fact that the obtaining of help from City institutions does not necessarily mean any serious loss of independence of policy . . 152

A list of sources of capital will be found on page . . 152

Consideration should be given to the creation of the equivalent of the American 'Small Business Administration', which makes long-term loans at favourable rates of interest 152–3

Where the Government is directly responsible for the supply of capital to an industry, it is important to plan the supply for a period of years and to avoid frequent changes to suit the short-term needs of economic policy . . . 153

Tariff and Other Protection

There is no *general* principle that protection favours (or retards) technical progress. Each industry must have separate consideration 156–7

In applying the Import Duties Act of 1958, the Treasury and the Board of Trade are supposed, in considering import duties, to have regard to 'the desirability of maintaining and promoting efficiency of production in the United Kingdom'; but it is not clear that the necessary machinery for research into this long-term question exists, nor that the Departments would take the effects on efficiency into consideration when imposing other types of protection. The Departments should make sure that proper and informed attention is given to these matters. We are not sure if the abolition of independent review by the Import Duties Advisory Committee was wise 158–9

Restrictive Practices

We doubt if issues of technical progress will be found to be of regular substantial importance in arguing cases before the Restrictive Practices Court; and we make no recom-

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[1] This group gave valuable help during the preparation of *Industry and Technical Progress*.

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